# Rio Blanco Oil Shale Company

## SCOPE OF WORK
## MODULAR DEVELOPMENT PHASE
## ENVIRONMENTAL MONITORING PROGRAM
## TRACT C-a OIL SHALE LEASE

January 15, 1979



Gulf Oil Corporation / Standard Oil Company (Indiana)
A General Partnership
9725 East Hampden Avenue, Denver, Colorado 80231

Revision 5.2
March 30, 1979

# SCOPE OF WORK

RBOSC Modular Development Phase
Environmental Monitoring Program

Tract C-a Oil Shale Lease

Gulf Oil Corporation
and
Standard Oil Company (Indiana)
A General Partnership
9725 East Hampden Avenue
Denver, Colorado 80231

SCOPE OF WORK

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

## LIST OF TABLES

LIST OF TABLES (Cont.)

## LIST OF FIGURES

SCOPE OF WORK
RBOSC MODULAR DEVELOPMENT PHASE (MDP)
ENVIRONMENTAL MONITORING PROGRAM

## 1.0 INTRODUCTION

This scope of work describes the tasks that are being conducted to fulfill RBOSC's obligations to monitor selected environmental parameters during development of oil shale resources on Tract C-a in northwestern Colorado. The work scope described herein specifically covers a three-year period as follows:

Year 3 - Jan. - Dec. 1979 (12 months)
Year 4 - Jan. - Dec. 1980 (12 months)
Year 5 - Jan. - Dec. 1981 (12 months)

This period represents the remainder of the Modular Development Phase (MDP) period. Although specific monitoring activities are described only for the MDP period, provisions for altering the program as development proceeds are discussed throughout the scope-of work. Both short-term and long-range objectives are described along with contingency sampling and plans for long-range trend analyses.

The monitoring program described herein basically addresses the period during which RBOSC will be constructing MDP retorts and associated support facilities, through the ignition and burn of five in-situ (MDP) retorts. The program is phased to allow certain aspects of the monitoring program to come on line as development progress dictates.

The overall objectives of the RBOSC MDP Environmental Monitoring Program are to meet lease stipulations to conduct a monitoring program before and during development operations to provide: a record of changes from conditions existing prior to development operations, a continuing check on compliance with lease provisions and all applicable Federal, State, and local environmental protection and pollution control requirements; timely recognition and notice of detrimental effects, if any; and a factual basis for revision or amendment of the lease stipulations. The specific objectives within each discipline area are designed to contribute to the achievement of these overall objectives by providing data which will meet the lease stipulations and will satisfy the specific requirements communicated to RBOSC through the Area Oil Shale Office.

Design of this program began during preparation of the Revised Detailed Development Plan (DDP). Initial steps included the review and analysis of environmental baseline studies data, the characterization of the Tract C-a environment, and an assessment of potential MIS development related environmental impacts. After completion of these tasks, the selection of components for inclusion in the monitoring program was made. This selection process was a multi-faceted problem which required the careful consideration of several key factors:

- Applicability of the research design to the Tract C-a situation
- Separation of essential versus non-essential program elements
- The scientific benefit of acquired data versus cost to obtain
- Reliability of acquired data and its application toward statistical analysis, ecosystem characterization, and impact assessment
- The sensitivity of the issue to public or political concern
- Long-range goals of the Prototype Leasing Program.

The goal was to formulate a monitoring program which would: satisfy the spirit and intent of the lease, the DDP, and the Conditions of Approval thereto; provide data to satisfy State and Federal permit requirements; assure accumulation of reliable, statistically sound data; clearly set forth program objectives; and provide a reasonable degree of flexibility in the program without exorbitant costs.

This goal has been realized with the finalization of this scope-of-work. The research design is tailored to maximize data recovery under site specific environmental and developmental conditions. Sampling sites have been located in areas most likely to experience development perturbations with control sites located outside the impact area whenever feasible. Air studies monitoring sites are located both up-wind and down-wind of planned emission sources, with provisions given to collect additional data once retorting is initiated to verify final placement of sampling equipment. Emissions data have been modelled to predict movement of pollutants away from the source and terrestrial monitoring sites have been set up in these locations. Whenever practicable, monitoring sites are multi-purpose, being used to collect data on several ecosystem components for comparison and analysis. As far as possible sampling frequencies and replications are designed to provide statistically reliable data without exercising sampling bias or adversely impacting the system.

With a few exceptions, non-essential elements of the program have been deleted in favor of elements more likely to yield meaningful results. Where baseline data have shown extremely high natural variability or unexplained fluctuations for a given component without an accompanying relationship to some identifiable driving variable, the component in question is normally de-emphasized in the monitoring program. Exceptions to this principle arise if the component is politically or environmentally sensitive (i.e., threatened or rare). Components selected for inclusion in the program, on the other hand, have been shown through baseline data analysis, impact (matrix) assessment, and professional judgement to be suitable monitoring parameters because they can be measured reasonably well, subjected to informative analyses, and evaluated against baseline data and/or the literature.

Omission of potentially important impact generators was prevented through use of a rigorous matrix assessment (modelling) technique in which all potential development-related impacts were systematically identified and ranked for each phase (Modular Development and Commercial) of activities. Forty-nine proposed actions (causative factors) were identified as capable of imparting impact to the environment. These causative factors (effect generators) were quantified to the greatest degree possible on the basis of mining plans, processing techniques, project schedules, disposal procedures, mitigation procedures and control plans. the effects of these 49 causative factors on 73 environmental receptor groups (effect receptors) were then qualitatively derived from analysis of baseline data coupled with best professional judgement. Effect receptors identified as moderately important to highly important were exposed to a research design evaluation to determine measurement suitability before inclusion in the monitoring program.

The parameters selected through the processes just described, plus those parameters specifically requested by the Area Oil Shale Supervisor appear in this monitoring program.

Within each technical section of this development-monitoring scope-of-work a stepwise procedure was used to plan the program as follows:

1) Review of overall objectives and formulation of task-specific objectives which are consistent with the overall objectives.
2) Statement of null hypotheses designed to test task-specific objectives as formulated in 1) above.
3) Derivation of suitable qualitative and quantitative analyses techniques to test the stated null hypotheses.
4) Review of program design to confirm compatibility between task-specific and overall objectives, and compliance with lease stipulations.

Additionally, the scope was designed to be flexible, with triggering mechanisms to alter the program (e.g., increase sampling frequency) if conditions warrant. Changes in the sampling regime may be triggered by a variety of events, including upset conditions or spills, identification of moderate to severe impacts in restricted regions, occurrence of identifiable widely spread impacts, impacts involving important or sensitive species, dangers to human health or safety, unexplained changes from baseline in ecosystem components, modifications from planned project procedures, changes in regulatory requirements, or requests from the Area Oil Shale Office.

Other pertinent elements which have been incorporated into this program include:

- Applications of the control/treatment sampling concept wherever feasible
- The goal to identify and quantify long-term trends and relationships.
- Provision to identify, monitor, and analyze key ecological interrelationships, results and conclusions.
- Management and accessibility to the data base.
- Plan for incorporating the information gained during the MDP program into the design of the Commercial Phase monitoring program.

In addition to this introduction this technical scope-of-work consists of the following sections:

2.0 Air Quality Studies
3.0 Meteorology Studies
4.0 Terrestrial Studies
5.0 Aquatic Studies

6.0 Hydrology Studies
7.0 Special Studies
8.0 Ecosystem Interrelationships
9.0 Reporting and Data Management

Information on objectives, rationale, methods, experimental design and data analysis is presented within each technical discipline. Report contents are described in Section 9.

## 2.0 AIR QUALITY STUDIES

Development of the tract may result in various disturbances to the air environment. An intensive effort is being made to quantify these disturbances. The ambient air quality of the area was measured extensively before development during the baseline studies, on a reduced scale during the interim period, and is again being measured extensively during the MDP period.

The baseline studies showed that, on the average, measurable values of CO, NO, $NO_x$, $H_2S$, and $SO_2$ were not present on the tract. Measurable quantities of methane ($CH_4$), total hydrocarbons (THC), ozone and total suspended particulates were detected on the tract. The average methane concentration was near the global average. Although federal guidelines exist for nonmethane hydrocarbons (obtained by subtraction of methane from total hydrocarbons), nonmethane hydrocarbon (NMHC) values were often produced that were unreliable due to the uncertainty in the measured quantities. Ozone was often detected in concentrations approaching the National Ambient Air Quality Standards, although the site is located in a pristine area. Particulates were measured at four locations on the tract. The average particulate concentrations measured were very low, which would be expected on the tract with the minimum activity characteristic of the baseline period.

Since only hydrocarbons and ozone of the gaseous constituents were found in measurable quantities during the baseline studies, most of the conclusions were centered around these pollutants. The hydrocarbons are significant primarily as precursors to photochemical smog. Over 90% of the average measured hydrocarbon concentration was methane, the least reactive hydrocarbon. The source of the nonmethane hydrocarbons could not be definitely identified. Relatively high ozone concentrations, such as found on the tract, are typical of many rural or remote locations. The cause of these elevated ozone concentrations is still subject to

6.0 Hydrology Studies
7.0 Special Studies
8.0 Ecosystem Interrelationships
9.0 Reporting and Data Management

Information on objectives, rationale, methods, experimental design and data analysis is presented within each technical discipline. Report contents are described in Section 9.

## 2.0 AIR QUALITY STUDIES

Development of the tract may result in various disturbances to the air environment. An intensive effort is being made to quantify these disturbances. The ambient air quality of the area was measured extensively before development during the baseline studies, on a reduced scale during the interim period, and is again being measured extensively during the MDP period.

The baseline studies showed that, on the average, measurable values of CO, NO, $NO_x$, $H_2S$, and $SO_2$ were not present on the tract. Measurable quantities of methane ($CH_4$), total hydrocarbons (THC), ozone and total suspended particulates were detected on the tract. The average methane concentration was near the global average. Although federal guidelines exist for nonmethane hydrocarbons (obtained by subtraction of methane from total hydrocarbons), nonmethane hydrocarbon (NMHC) values were often produced that were unreliable due to the uncertainty in the measured quantities. Ozone was often detected in concentrations approaching the National Ambient Air Quality Standards, although the site is located in a pristine area. Particulates were measured at four locations on the tract. The average particulate concentrations measured were very low, which would be expected on the tract with the minimum activity characteristic of the baseline period.

Since only hydrocarbons and ozone of the gaseous constituents were found in measurable quantities during the baseline studies, most of the conclusions were centered around these pollutants. The hydrocarbons are significant primarily as precursors to photochemical smog. Over 90% of the average measured hydrocarbon concentration was methane, the least reactive hydrocarbon. The source of the nonmethane hydrocarbons could not be definitely identified. Relatively high ozone concentrations, such as found on the tract, are typical of many rural or remote locations. The cause of these elevated ozone concentrations is still subject to debate, and may be due to natural reactions onsite, stratospheric injection, long range transport, or some combination of these processes.

A modeling study was completed to determine where the areas of maximum concentration of certain pollutants produced during the MDP would be, and to provide an estimate of these concentrations. The pollutants modeled were $SO_2$, $NO_2$, particulates, and NMHC. A short-term and a long-term model were used to evaluate the expected impacts during various time periods. In general, the study showed that applicable air pollution standards would not be violated, and the highest concentrations would be encountered to the west of the tract. This effect is a result of the rise in terrain to the west.

A matrix analysis was completed for the project to estimate potential development impacts on the biotic and abiotic components of the ecosystem at the tract. Particulate concentrations are expected to be affected to a slightly or moderately important degree by construction activity, ore blasting and storage, and during commercial development, power generation. Gaseous concentrations are expected to be affected to a slightly or moderately important degree by surface retorting, power plant generation, and the increased manpower on the site.

## 2.1 AMBIENT MONITORING

### A. Gaseous Constituents

1. Objectives - With the increased activity on the tract during the MDP period certain changes may occur in the ambient air quality due to the construction of the facilities and by the processing of the oil shale. The purpose of the air quality monitoring program is, therefore, to provide a quantitative basis for evaluating any changes in the ambient constituents. Specific objectives are:

- To measure the ambient levels of specific air quality parameters and determine long-term trends in the air quality around the tract.

- To provide air quality data which can be compared to the relevant state and federal air quality standards.

- To provide air quality data which allows the implementation of a control/treatment concept in assisting in the evaluation of tract influences on the ambient air quality.

- To provide a continuous time series of air quality data, which will allow, in conjunction with the meteorological data, some analysis of the air quality impact of emissions on the tract.

The air quality data and technical interpretation will also be available for studies by other disciplines of cause/effect relationships, e.g., changes in the growth rate of flora or the pH of local streams.

2. Methods - Certain air quality gaseous constituents are monitored continually with automated instrumentation. The pollutants being measured were chosen because either MDP operations are expected to release these pollutants, or because they are necessary to characterize the air quality of the region. The data are recorded with an automatic data acquisition system backed up with strip chart recorders. The instruments are housed in strategically located, environmentally controlled shelters. The data acquisition system scans each parameter 3.6 times each minute and computes a running 15-minute average. The average value is recorded on magnetic tape at the end of each quarter hour. Hourly averages are computed from the 15-minute values.

a. Parameters - The air quality parameters monitored in the vicinity of the tract are $SO_2$, $H_2S$, CO, NO, $NO_x$, and $O_3$. Total hydrocarbons and $CH_4$ were measured at Site 1 until February 1978, when they were discontinued with the approval of the AOSO, due to the inaccuracy of the NMHC calculation and the current state-of-the-art for automatic instrumentation of this parameter.

b. Monitoring Locations - Figure 2.1 illustrates the monitoring locations around the tract. Site 1, just west of the tract boundary, is the location at which the greatest number of air quality and meteorological parameters have been monitored to date. Continual monitoring at this location will provide continuity with the baseline data set so that changes in the ambient air quality may be detected. In addition to the data set continuity, Site 1 provides a valuable measurement of the ambient air quality of the region (the control site) due to its location, which is frequently upwind of the tract development.

Site 3, also operational during the baseline period, is located in the approximate center of the drainage valley leading away from the northeast corner of the tract. Air quality degradation from tract operations should be evident first at Site 3 (the treatment site) for two reasons: the prevailing westerly winds will carry the tract emissions over Site 3, and nighttime drainage winds from the tract development area will tend to carry the low-level emissions down to this drainage valley where they will be trapped during the frequent nocturnal inversions that occur in the valley. Air quality measurements at Site 3 were discontinued after the baseline period, and have gradually been reactivated during the first part of the MDP. The complete set of instrumentation at the site is currently scheduled to be operational by September 1979 (Table 2.1). Beginning in September 1979, $SO_2$ and $H_2S$ will also be monitored at Site 2 as long as existing equipment continues to operate.

Site 5 is shown on Figure 2.1 as being located in the general area where the maximum 24-hour and 3-hour sulfur dioxide concentrations resulting from MDP activities are expected to occur. Following the ignition of the first retort, a field survey program will be conducted to establish the

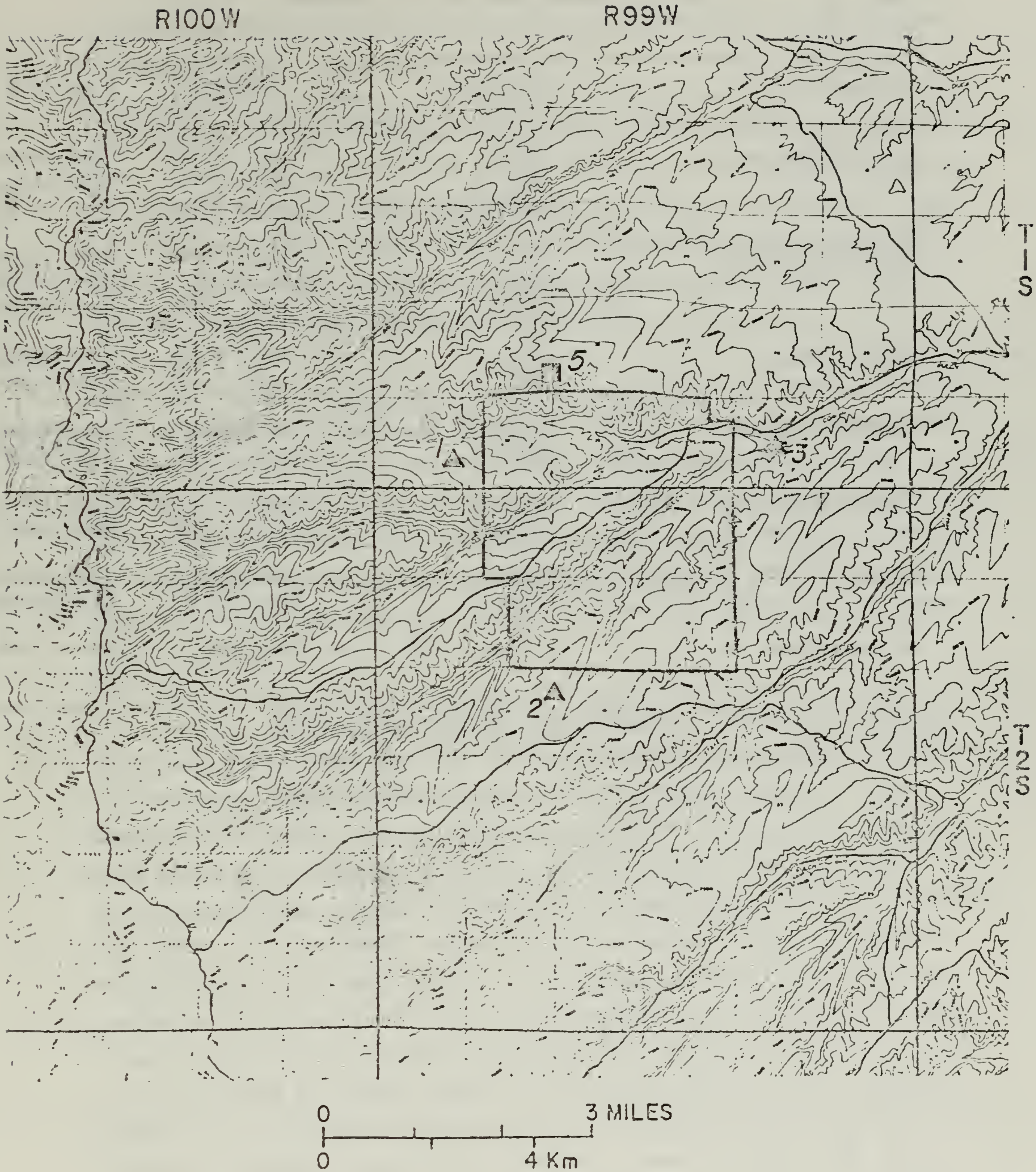



Figure 2.1. Locations of Air Studies Monitoring Shelters (Δ) and Proposed $SO_2$ Monitoring Site (□) for the MDP Environmental Monitoring Program

Table 2.1. Air Quality Studies Monitoring Schedule

| Parameter | Location | Start Date | Frequency |
|---|---|---|---|
| Sulfur Dioxide | Site 1 | Sept. 1977 | Continuous |
| | Site 3 | Jan. 1978 | Continuous |
| | Sites 2,5 | Sept. 1979 | Continuous |
| Hydrogen Sulfide | Site 1 | Sept. 1977 | Continuous |
| | Site 3 | Jan. 1978 | Continuous |
| | Site 2 | Sept. 1979 | Continuous |
| Nitric Oxide | Site 1 | Sept. 1977 | Continuous |
| | Site 3 | Sept. 1979 | Continuous |
| Nitrogen Oxides | Site 1 | Sept. 1977 | Continuous |
| | Site 3 | Sept. 1979 | Continuous |
| Carbon Monoxide | Site 1 | Sept. 1977 | Continuous |
| | Site 3 | Sept. 1979 | Continuous |
| Ozone | Site 1 | Sept. 1977 | Continuous |
| | Site 3 | Nov. 1979 | Continuous |
| Particulates | Sites 1,2&3 | Dec. 1977 | Every 3rd Day |

precise location of Site 5. The frequency of occurrence of the maximum 24-hour and 3-hour $SO_2$ concentrations will be examined in relation to persistent winds in the area. By sampling with manual techniques during those meteorological conditions expected to cause the highest concentrations, an estimate will be made of the levels of sulfur dioxide that can be expected to occur during the MDP, and a practical location for Site 5 will be established. These ambient air concentration measurements will be used to determine whether continuous monitoring for sulfur dioxide will be required in this area during the MDP.

The locations of the air quality monitoring systems at Sites 1, 2, and 3 will be periodically reviewed during the MDP period as development plans are finalized to insure that these sites are representative of the conditions for which they were designed to measure. If a review indicates that relocation of one of the sites is required, with the concurrence of the AOSO, such a change will be incorporated into the monitoring system. The selection of the new site will be based on the earlier tracer tests and the latest MDP data.

c. Monitoring frequency and schedule - The onsite instrumentation presently being used for gaseous component measurement is capable of continuous operation when supplied with reliable commercial power. When the instruments are serviced and maintained on a regular schedule, data recovery is expected to be near 90 percent on an annual basis. This recovery rate exceeds the federally recommended minimum of 75 percent (EPA 1976). The automatic data acquisition system at Site 1 records meteorology and air quality data. This system automatically scans all parameters 3.6 times each minute, and computes a running 15-minute and 1-hour averages of the meteorological and air quality parameters. These data are stored on magnetic tape. All time designations are in local standard time (Mountain Standard), and the seasons of the year are defined as: Spring - March, April and May; Summer - June, July, and August; Fall --September, October, and November; and Winter - December, January, and February. Data hours are computed from data acquired during the hour so that the 0200 data point is the data average from 0130 to 0230 hours. The 15-minute data averages are not ordinarily utilized, but are recorded and are available for future requirements, if necessary.

d. Instrumentation and data acquisition techniques - Gas detection instrumentation was installed at the monitoring sites early in 1975. This equipment has an expected service lifetime of at least two to four more years. On February 18, 1975 the Environmental Protection Agency (EPA) published rulings on Ambient Air Monitoring Reference and Equivalent Methods (FR Vol 40 No 33, February 18, 1975) which defined standards for the detection of certain pollutants for regulatory agencies. The new standards rule out certain detection techniques and instrument designs, but allow a period of five years for continued use of these instruments, or under certain conditions, for the rest of their useful life. Future instrumentation designs require a certification of certain test results by the EPA.

The det tion methodology of the tract air quality monitoring instrumentation meets the requirements of reference methods. However, some of the instrument models have not, and will not, receive certification that their performance meets the published Federal EPA equivalency requirements. Frequent calibrations, quality control charts of zero and span drifts, and careful maintenance will provide a demonstration of equivalence in instrument performance for all parameters monitored except sulfur dioxide. The existing instruments ($SO_2$) are of a fixed sensitivity range which do not provide the required resolution of one percent of full scale. Baseline sulfur dioxide data levels were consistently below the reliable threshold of detection of this instrument.

The instrumentation will be replaced if it gives unsatisfactory performance due to age or general wear. The monitoring system will also be updated with state-of-the-art instrumentation if AOSO or EPA deems it necessary due to significant changes in instrument technology.

Two parallel methods are used for data acquisition from the air quality monitoring instruments. In the primary system, the instrument output signal is digitized electronically, averaged by a computer, and recorded on magnetic tape. In the backup system, the instrument output signal is recorded on a channel of a multipoint strip chart recorder.

e. Data handling and quality assurance procedures - Magnetic tapes and strip chart records are transferred from the site to the data reduction group on a bi-weekly basis. The tapes are logged in by a programmer, the data dumped in easily readable format, reviewed by an analyst, and filed for quarterly batch processing. The strip charts are logged in by a data reduction technician, reviewed by an analyst, and filed. If data are missing from the magnetic tape record, the data reduction technician reduces strip chart data by timing the record and reading the air quality parameters as percent of scale. Documented work instructions for defining missing data, determining hourly averages, minimum detectable level, etc., are used for manual data reduction. Manually reduced data are punched on cards and merged with the magnetic tape data. The digital system is checked on a one-hour-per-week basis by comparing the digital values of all parameters with the analog values derived from the strip charts for the same time period.

Operation and maintenance of the air quality instrumentation are performed by site technicians. A station log is maintained in which relevant information is recorded each time the facility is visited. In addition, the technician has a site-specific checklist on which to record instrument performance tests, and a documented work instruction for site surveillance. These records are completed at least once each calendar week. Performance tests require a zero and span check of all instruments. These tests consist of switching the instrument sample line from the ambient air intake manifold to a standard gas sample obtained either from a standard gas cylinder or a permeation tube source that has been standardized. A quality control chart is maintained to record the results of the zero and span tests. Control limits are established to maintain acceptable instrument performance.

Calibration of the air quality instrumentation is performed at least once each 90-day period. These calibrations, along with the running control charts, are used to establish the instrument accuracy. The calibrations are performed in accordance with documented work instructions. The gas cylinders contain known concentrations of CO and NO, and are acquired as necessary from vendors who can furnish traceability of accuracy to the National Bureau of Standards.

Scale factors for each parameter are established from the nominal span settings of the instruments. Corrections to these scale factors are developed from the internal quarterly calibrations, if analysis of the calibration results show that corrections are necessary.

The final scale factors are applied to the air quality data, which are assembled into a complete and finished data set on a six-month basis. This data set is then combined with the meteorological data and written on a magnetic tape with a SAROAD header file.

The site technician also cooperates with the EPA-sponsored program "Quality Assurance in Support of Energy Related Monitoring Activities in the Western United States," which provides a quarterly round-robin calibration backup check using independent test gases and instrumentation. Quarterly dynamic gas calibrations are performed with test gases which are independent of the gas reference cylinders maintained on site for the weekly dynamic tests. In addition, this QA program tests the standard gas cylinders which are maintained at the site to verify the concentrations given by the vendors.

Additional quality assurance will be provided through semi-annual internal audits. These include site visits, and are designed to insure that both site personnel and technical office personnel are following prescribed procedures as given in this work scope, the work instructions and applicable sections of the RBOSC QA manual.

3. Experimental Design and Data Analysis Procedures - The objective of the air quality monitoring program is to document quantitatively any changes in the air quality around the tract. There are two methods by which this can be done: the baseline data can be used as a control and tested against MDP data for those monitoring sites that have been active during both periods; or the background monitoring site (Site 1) can be used as a control and tested against the monitoring site which is expected to be affected by tract operations (Site 3).

The following hypotheses will be tested:

$H_0$: There is no significant difference in the concentrations of gaseous pollutants measured during the baseline period and the Modular Development Phase at each monitoring station.

$H_0$: There is no significant difference in the concentrations of gaseous pollutants monitored at any of the RBOSC air studies sampling sites.

The measurements of air quality data are the only continuous air studies data taken on tract which are expected to show some effect of tract development. Because the air quality monitoring is performed on a continuous basis, the sample sizes will be very large. Each pollutant measured will be tested according to the hypotheses given above by statistically comparing monthly, annual and seasonal means between data sets.

The pollutants currently measured on the tract fall into two categories: those that have concentrations exceeding the threshold of the instrumentation ($O_3$), and those whose concentration are generally less than the instrument threshold, ($SO_2$, $H_2S$, CO, NO, $NO_x$). Where the parameters generally have concentrations below the thresholds of the instrumentation, statistical comparisons cannot be made between control and treatment data sets. However, it will be obvious if the MDP operations produce an increase in emissions such that the mean concentration of a pollutant exceeds the instrument threshold. Comparison of the ozone concentrations between data sets will take into account the diurnal and annual cycles as well as the mean concentrations.

In addition to the mean of each parameter, the air quality analysis will include extensive study of individual pollutants and interactions between pollutants. For instance, it has been noted that the occasional increases in $NO_x$ concentrations appear to always be accompanied by decreases in the $O_3$ concentrations. Apparently the gas phase reaction between NO and $O_3$ occurs onsite, and needs to be studied in more detail. Another interesting problem is the high ozone concentrations measured at such a remote site. The simultaneous measurement of ozone at two sites in conjunction with extensive supporting meteorological data will allow an analysis of topographic effects on ozone concentrations. The purpose of the air quality data analysis will be to gain a better understanding of the pollutant sources and sinks and the dynamic interactions affecting pollutant concentrations on the tract. The on site meteorolgical data will be used extensively to aid in the air quality analysis.

A high degree of flexibility will be maintained in the analysis program so that unexpected or interesting results can be studied in detail when such a course of action appears to be warranted. For instance, an increase in measured $SO_2$ concentrations on the tract after the retort burn is started is possible and will be watched very carefully. A portable monitoring system will be available at that time to better characterize the resulting $SO_2$ concentrations. Changes in the permanent monitoring system and the analysis procedure will be made after the retort burn has begun, if initial monitoring results indicate that this is necessary.

Comparisons will be made between monitored results at each site and the federal and state regulatory standards.

Close liaison will be maintained between the air studies team and the biological and hydrological teams involved in monitoring programs on and near the tract. Guidance in determining the areas of maximum pollutant concentrations and probable maximum environmental impact will be provided to these teams based on current air quality data, so that their monitoring programs can be designed and adjusted to best measure possible effects due to the changes in the tract environment. In this manner, both short-term and long-term effects on the biotic and abiotic factors can be properly measured and analyzed.

B. Particulates

1. Objectives - Suspended particulate matter is of concern on and near the tract since it is controlled by federal and state regulations. It is, therefore, extensively monitored in the environmental program. Specific objectives are:

- To provide data which can be compared to the relevant federal and state ambient air quality standards.

- To provide a data set during tract development which can be compared with the baseline data set.

- To attempt to correlate measured particulate loadings with specific sources and with other significant air quality and meteorological parameters.

The concentration of suspended particulate matter on the tract was shown to be low during the baseline studies. A general trend is evident of very low ambient particulate concentrations during the winter months, due at least in part to the snow cover, and higher concentrations during the warm, dry summer.

This background particulate matter will be augmented by three types of sources during the MDP period. The first two source types are the increased traffic on the network of dirt roads around the tract and the construction activity in the center of the tract. After the initial construction phase is completed, the contribution due to construction activity should decrease. The third source of particulates will be from oil shale processing after the retort burn is initiated. As a result, the type of source and, therefore, the concentration of suspended particulate matter will change with time during the MDP. The changing character of the particulate problem will be carefully studied and analyzed, in consultation with AOSO and EPA. RBOSC will cooperate with the EPA in providing filters for analysis of size and composition as a part of the EPA's proposed visibility program.

2. Methods

a. Parameters - Total suspended particulates will be measured according to the federal reference method using high volume samplers. In addition, sampling of particulates for size distribution will be done utilizing an Anderson particulate sampling head on one of the high-volume samplers.

b. Monitoring Locations - High volume samplers are operated at Sites 1, 2, and 3 and are located 20 feet above ground elevation (Figure 2.1). Sites 1 and 2 are located generally upwind of the tract development and therefore serve as control sites. Site 3 is located generally downwind and in a gulch that drains the development area (as described earlier). As a result, it serves as a treatment site. Unfortunately, the situation is complicated by the location of the main tract access road approximately 100 yards from the Site 3. The representativeness of the Site 3 particulate sampler as a treatment site for the MDP operations should improve by mid-year 1979, when the tract access road is scheduled to be paved.

The suitability of the monitoring locations will be subject to periodic review based on analysis of the data. If it appears that additional samplers or relocation of existing samplers are appropriate, changes will be made to the monitoring program after discussions with the AOSO.

c. Monitoring Frequency and Schedule - The three particulate monitors have been in operation since the start of the MDP (Table 2.1). A 24-hour high-volume sample is taken at each of the three sites every third day. A day is defined as 0000 hours to 2400 hours. The schedule is flexible and can be changed if the data analysis shows the need for it, or if special tests, such as a short-term visibility study, suggest a change. The schedule for operation of the Anderson particulate sizing head has not yet been established. Maximum utility of the instrument as well as cost effectiveness would result from including a size distribution study with the visibility study. Details of this program will be worked out with the AOSO and EPA.

d. Data Acquisition Techniques and Instrumentation - General Metal Works high volume samplers with Sierra flow controllers are used to acquire samples. An electric clock timer controls the on-off cycle of the sampler. Unexposed filter mats are conditioned and weighed at the air quality laboratory using the EPA reference technique. The balance is standardized with class S weights. Filters are coded and supplied to the field technician ready for use. Exposed filters are cycled through the same analytical procedure upon their return to the air quality laboratory.

e. Data Handling and Quality Assurance Procedures - The high volume sampler flow rates are calibrated quarterly with a standard orifice plate to determine the flow rates to be used to calculate particulate concentration. The standard orifice plate has been calibrated at EPA's Region VIII laboratory in Denver.

Each exposed filter carries with it a location verifier, and before and after flow meter readings taken by the field technician. Weight determinations are maintained in a log in the air quality laboratory and filters are stored for future reference if chemical composition or radioactivity levels are required. In accordance with EPA recommendations, a minimum of 10 percent of the filters are reconditioned and reweighed as a quality assurance check.

The field technician cooperates with the EPA Western Energy Quality Assurance Program in the parallel calibration of sampler flow rates. The Rockville air quality laboratory also cooperates in inter-laboratory weight standardization tests.

The particulate data will be stored on magnetic tape on a semi-annual basis for future reference.

3. Experimental Design and Data Analysis Procedures - The purpose of the monitoring program is to define and quantify changes in the total suspended particulate matter around the tract as a result of tract development. To that end, the following hypotheses will be tested:

$H_0$: There is no significant difference in the concentration of total suspended particulate matter at each monitor before and during development.

$H_0$: There is no significant difference in the concentration of total suspended particulate matter between the control and the treatment sites.

These hypotheses will be tested on an annual and seasonal basis by statistically comparing the geometric means between data sets. A more important analysis is the determination of particulate sources and the transport of these particulates, using the onsite meteorological data. As mentioned earlier, the sources of particulates are expected to change as the Modular Development Phase progresses. The data analysis will serve as a feedback mechanism to suggest adjustments to the monitoring program as well as to indicate the need for additional controls.

The particulate data will be reviewed on a quarterly basis, and a report satisfying the requirements of the conditional PSD permit will be submitted to the AOSO and EPA.

## 2.2 SOURCE EMISSION MONITORING

Permits and approvals must be obtained prior to construction and operation under:

- Federal significant Deterioration of Air Quality Regulations (U.S. Environmental Protection Agency, 1974);
- Colorado Air Quality Control Regulations (Regulation 3) (Colorado Air Pollution Control Commission, 1975).

The development of Tract C-a is a prototype oil shale development project and the specific requirements for source emission monitoring programs are not defined. The procedures for obtaining permits allow the agencies to require stack monitoring and stack sampling to ensure compliance with emission standards. The RBOSC source monitoring program will consider the pollution control devices employed, stability of operation, and the relative significance of each pollutant. Extensive discussions will be held with regulatory agencies as the engineering monitoring design progresses. Source monitoring and stack sampling that are needed to comply with the terms of permits and approvals will be included in the final design. Sampling ports and access facilities will be installed on each source which is controlled by air pollution control devices. Trace element analyses of the thermal oxidizer flue gas will be made during the Modular Development Phase under DOE funding. The accuracy of the measurements in both the soils and stack programs and the concentrations found will be important considerations in determining if a continuing program is justified on the basis of its scientific utility and cost effectiveness.

DOE is currently developing an intensive stack monitoring program. This program will be submitted to the AOSS as well as to the CDOH and EPA for review prior to finalization of the program. Guidelines in the recent EPA document entitled "Sampling and Analysis of Low Molecular Weight Sulfur Compounds in Process Effluents" (Research Triangle Park, Contract No. 68-02-2156) will be used as a basis of reference in design of the RBOSC program.

## 3.0 METEOROLOGICAL STUDIES

The climatology of the area was described in the Final Environmental Baseline Report. Briefly, the climate can be characterized as semi-arid, with hot summers and moderately cold winters. Severe weather is very uncommon in the region. The skies are clear most of the year, and the humidity is generally quite low. The combination of bright sunshine and strong nocturnal radiational cooling leads to large diurnal temperature changes. Thus, in the absence of high winds, valley winds are quite common in the area.

The local climate is important because the tract is intersected by several gulches, resulting in large topographic variations conducive to the development of mountain-valley winds. Since the local air flows have a large influence on atmospheric dispersion of pollutants, the gulches (which influence the local air flows) have a strong effect on the air quality of the area. It has been noted that inversions occur frequently in the gulches. As a result, pollutants entering the gulch system tend to stay there, producing locally high concentrations. This phenomenon was observed in the tracer study.

The upper air studies during the baseline period showed that the average mixing height at Site 1 varies from 600 feet above ground level during the Fall to 3100 feet above ground level during the Summer.

The matrix analysis assumed that tract development would have no effect on the meteorological parameters, with the possible exception of the atmospheric water vapor content (relative humidity or dew point). As a result, the meteorology of the tract only has an indirect role through its influence on the dispersion of pollutants on the tract.

## 3.1 AMBIENT MONITORING

### A. Objectives

- To develop a climatological data base, which can be used by discipline specialists studying the tract.
- To develop a meteorological data base that can be used in atmospheric dispersion analysis.
- To determine if meteorological conditions influencing atmospheric dispersion are similar during the baseline and the Modular Development Phase.

### B. Methods

1. Parameters - The following parameters are being measured as a continuation of the baseline data acquisition program:

- 10 m and 60 m wind directions
- 10 m and 60 m wind speed
- 10 m ambient temperature
- 10 m - 60 m differential temperature
- Precipitation
- Solar radiation
- Dew point
- Barametric pressure
- Snow depth and accumulation

2. Monitoring Locations - Meteorological data are collected at Sites 1, 2, and 3. The most extensive monitoring program is at Site 1, coincident with the most extensive air quality monitoring system. Ten parameters are currently being measured at Site 1, which is equipped with a 60 m instrumented tower (Table 3.1). Measurements of wind speed and direction, and ambient temperature are made at monitoring Sites 2 and 3 at the 10 m level.

Table 3.1. Meteorology Studies Monitoring Schedule

| Parameter | Location | Start Date | Frequency |
|---|---|---|---|
| Wind direction (10m) | Sites 1, 2, 3 | Sept. 1977 | Continuous |
| Wind direction (60m) | Site 1 | Sept. 1977 | Continuous |
| Wind speed (10m) | Sites 1, 2, 3 | Sept. 1977 | Continuous |
| Wind speed (60m) | Site 1 | Sept. 1977 | Continuous |
| Ambient temperature (10m) | Sites 1, 2, 3 | Sept. 1977 | Continuous |
| T (1060m) | Site 1 | Sept. 1977 | Continuous |
| Precipitation | Sites 1, 2, 3 | Oct. 1977 | By event |
| Barometric Pressure | Site 1 | Jan. 1978 | Weekly |
| Solar radiation | Site 1 | Sept. 1977 | Continuous |
| Dew point (10m)* | Site 1 | July 1978 | Continuous |
| Snow Depth & Accumulation | Sites 1,2,3 | Nov. 1978 | By event |

* Relative Humidity: Sept. 1977 - July 1978

The site locations are unchanged from the baseline studies and thus provide for temporal as well as spatial data analysis. The meteorological data will be used in interpretation of the air quality data and, consequently, are collected at the same locations.

3. Monitoring Frequency and Schedule - Meteorological parameters are monitored continuously by the automatic digital data acquisition system, backed up by the strip chart recorders. The data acquisition system scans each parameter approximately 3.6 times each minute and computes a running 15-minute average. The average value is recorded on magnetic tape at the end of each quarter hour. Hourly averages are computed from the 15-minute values during data reduction, in a similar manner to the calculation of air quality data.

The period of record of monitored meteorological data is given in Table 3.1. Both the schedule and monitoring locations are subject to periodic review. If analysis of the air quality or meteorological data during the MDP monitoring program indicates that a change in, or addition to, the monitoring network is necessary, this will be done, after discussions with the AOSS.

4. Data Collection Techniques and Instrumentation - The present meteorological sensors for wind speed and direction have performance specifications which meet or exceed the strigent requirements of the Nuclear Regulatory Commission (NRC) Regulatory Guide 1.23. To maintain these specifications, these sensors are replaced semi-annually with identical units calibrated by the Naval Oceanographic Instrument Center, traceable to the National Bureau of Standards.

The temperature sensors are platinum resistance elements that have specifications which meet or exceed the requirements of NRC Regulatory Guide 1.23. To maintain the accuracy of the temperature system, the system is calibrated against a certified quartz thermometer in absolute and differential temperature baths on a semi-annual basis.

The dew point measurement instrument is factory calibrated to an accuracy which exceeds the accuracy requirements of NRC Regulatory Guide 1.23. The accuracy of the dew point sensor is maintained by proper servicing in the field.

The precipitation gages (tipping bucket and recording types) are calibrated semi-annually by adding precisely measured volumes of distilled water and checking the instrument response. The accuracy is maintained by keeping the collectors clean, and the mechanical mechanisms clean and free of insect intrusion. The wedge precipitation gages, which are permanently calibrated at the factory, are periodically checked to insure that they are clean and their exposure is satisfactory.

The solar radiation sensor is factory calibrated annually. The accuracy is maintained by keeping the collector clean and the field of view unobstructed.

The recording devices are voltage operated and are calibrated with certified test equipment by applying a series of test voltages that permit the determination of sensitivity and linearity.

The geographic azimuth accuracy of the wind direction sensors is established with sighting telescopes using surveyed landmarks. Snow depth and accumulation are measured daily when snow is present by reading the depth on a standard metric ruler. Notes on new snowfall are also recorded.

5. Data Handling and Quality Assurance Techniques - The meteorological data are recorded on magnetic tape at the site with concurrent air quality data. The tapes are returned to the data center for computer listing, scaling, and data fill-in from strip chart reduction, where required. The new data are reviewed for reasonableness prior to processing.

One hour of randomly chosen analog meteorological data is reduced per week and compared with the data from the automatic digital system as a check to insure that the digital system is functioning properly.

Copies of the calibration data are forwarded to the data reduction group, where they are reviewed. If the review indicates that the data are in need of correction, this is done at this time. The data are then printed out in a final listing semi-annually and reviewed for resonableness. Permanent storage of the data is on magnetic tape with a SAROAD leader.

C. Experimental Design and Data Analysis Procedures

The principal utility of site meteorological data is its application in interpreting observed changes in air quality. However, the data set is compared with baseline data to insure that it is representative. The comparison is as follows:

$H_o$: There is no significant difference between meteorological conditions measured during baseline studies and during the Modular Development Phase.

The hypothesis will be tested by performing analyses identical to those of the baseline studies -

- Annual and seasonal wind roses for each sensor at each location.
- Annual and seasonal maximum, minimum and mean values.
- Monthly, seasonal, annual and event precipitation totals.
- Frequency of occurrence of stability class derived from T data
- Joint frequency distribution of wind speed and direction by stability class on an annual basis

These statistics will be compared for both periods to determine if the data sets are similar.

Because the meteorological data system is designed to meet the stringent NRC Regulatory Guide 1.23 requirements, it will generally exceed the requirements of the EPA for monitoring data. The collected data should serve as an excellent data set for use in dispersion analyses, and for use in special studies of the air quality data. It is important that the data base be of maximum utility. Consequently, the monitoring program will be periodically reviewed in light of the results of the analyses and projected future requirements.

The meteorological data base will be available to the other investigators working on the tract. Close liaison will be maintained to assist these workers in providing or interpreting the meteorological data for use in their own specialities. Snow depth and accumulation data will be made available to biologists and hydrologists studying the tract for assessment in their particular disciplines.

## 3.2 SPECIAL STUDIES

### A. Visibility

Visibility measurements were made during the baseline by using densitometers to determine the visual range on photographic exposures of identified geographical locations at a number of known ranges from the camera. Measurements were taken over a period of two years. In general, visibility at the site was excellent, but there was a high variability on both a daily and seasonal basis. The greatest seasonal difference in mean visual range was between the Spring and Fall seasons, with the latter having the greater range. These seasons were, therefore, chosen for visual range measurements during the first year of MDP. Due to the large seasonal and diurnal variation, the number of samples required to obtain a representative sample is relatively high.

The Clean Air Act, as amended in 1977, declared that the prevention of visibility impairment from manmade air pollution is a national goal in mandatory Federal PSD Class I air quality areas. Although the oil shale tracts are not Class I areas, mandatory Class I areas can be seen from the tract. Changes in visibility are, therefore, a concern because of the possible impact on nearby sensitive areas.

1. Objective - To provide measurements of visibility such that trends in the data can be distinguished from seasonal or diurnal fluctuations.

2. Methods - The program, which involves the use of a photometric technique in 1978, will be changed in 1979. The current photometric technique will most likely be superseded by special visibility instrumentation. There is a trade-off between visibility measurements over long pathlengths of 50-100 miles (such as the photometric method) and measurements over very short pathlengths (e.g., with the nephelometer). Both techniques have limitations: with long pathlengths, the visibility measurements may be integrating over distances in which the visibility is affected by other than local emissions; with short pathlengths, the visibility measurements may not be representative of location conditions. Due to the measurement problem, and the recent mandates laid down by the 1977 Clean Air Amendments, visibility measurements and federal and state requirements are in a state of flux.

The 1979 visibility program will be developed only after close consultation with the AOSO and EPA. At this time, the most likely program will include the use of the telephotometer. However, this is still very much open to discussion.

3. Experimental Design and Data Analysis Techniques - Both the experimental design and the data analysis techniques will depend upon the type of visibility program implemented in 1979. Nonetheless,

certain design criteria must be met, in particular, sufficient measurements must be taken to insure reproducibility and to distinguish trends in the data from data variability.

## B. Noise

Noise levels measured during baseline indicated that the background levels were low. Measurements ranged from 24 to 51 dB with occasional peaks above this maximum due to airplane overflights and wind interference. Development on tract is anticipated to result in increased noise levels in the immediate vicinity of ongoing activities and near roadways as a result of increased traffic flow. Wildlife, especially big game animals, are expected to become acclimated to the noise within a short period of time and to resume normal activity patterns except in areas immediately adjacent to the mine site and in areas where the noise source is erratic.

MSHA and State of Colorado regulations relative to worker exposure to noise and ambient levels are stringently adhered to on Tract C-a. Qualified tract personnel monitor noise on a regular basis and impose restrictions on workers and equipment as necessary to assure compliance with applicable regulations. This program is conducted independently of the environmental studies and is not discussed herein. A description of mine worker safety regulations and procedures are available on Tract C-a for inspection upon request. The noise program discussed below addresses the environmental aspects of the noise program.

1. Objectives - Regulations regarding allowable noise levels have been promulgated for the safety and well being of humans. None of the existing regulations apply to effects of noise on wildlife, although some research has been conducted in this area (EPA 1971. Effects of Noise on Wildlife and Other Animals. Memphis State University). The objectives of the environmental noise program are to:

- Provide a data base on relative noise levels at various distances from the sources on tract
- Determine maximum noise levels at the tract boundaries likely to occur as a result of tract operations
- Provide data for use by wildlife biologists in assessing the overall impacts of tract development on wildlife behavior and use of the study area.

2. Methods - Noise measurements will be made at 16 locations on a quarterly basis. These locations represent a series of concentric circles from the construction area out to the borders of Tract C-a (Figure 3.1). Each permanent site will be flagged and visited once each quarter. In addition to these quarterly measurements, opportunistic readings will be taken in construction or mining areas and at several selected off tract locations, during peak levels of activity to determine the sources and levels of noise, and the distances at which the sounds can be heard.

Sound level readings will be taken with a Bruel and Kjaer Sound Level Meter, Type 2205. The accurate range of this instrument is 20 to 130 dB. A Condenser Type 1, ANSI S1.12 omnidirectional microphone will be used to receive noise impulses. The sound level meter will be calibrated as necessary with a Bruel and Kjaer Sound Level Calibrator, Type 4230 operating on a frequency of 1000 Hz±1%. Wind speed will be determined with a Taylor Instrument Company, handheld anemometer. Wind direction will be estimated with the aid of a compass.

The sound level meter will be calibrated using the Sound Level Calibrator before each survey. Wind speed (mph), wind direction (degrees), and time will be recorded at the start of each survey. Highest and lowest values on the meter during a 20-second period will be recorded for each site. Measurements will be repeated five times. Comments noting unusual circumstances (i.e. jet overhead) and general conditions during the reading will be recorded.

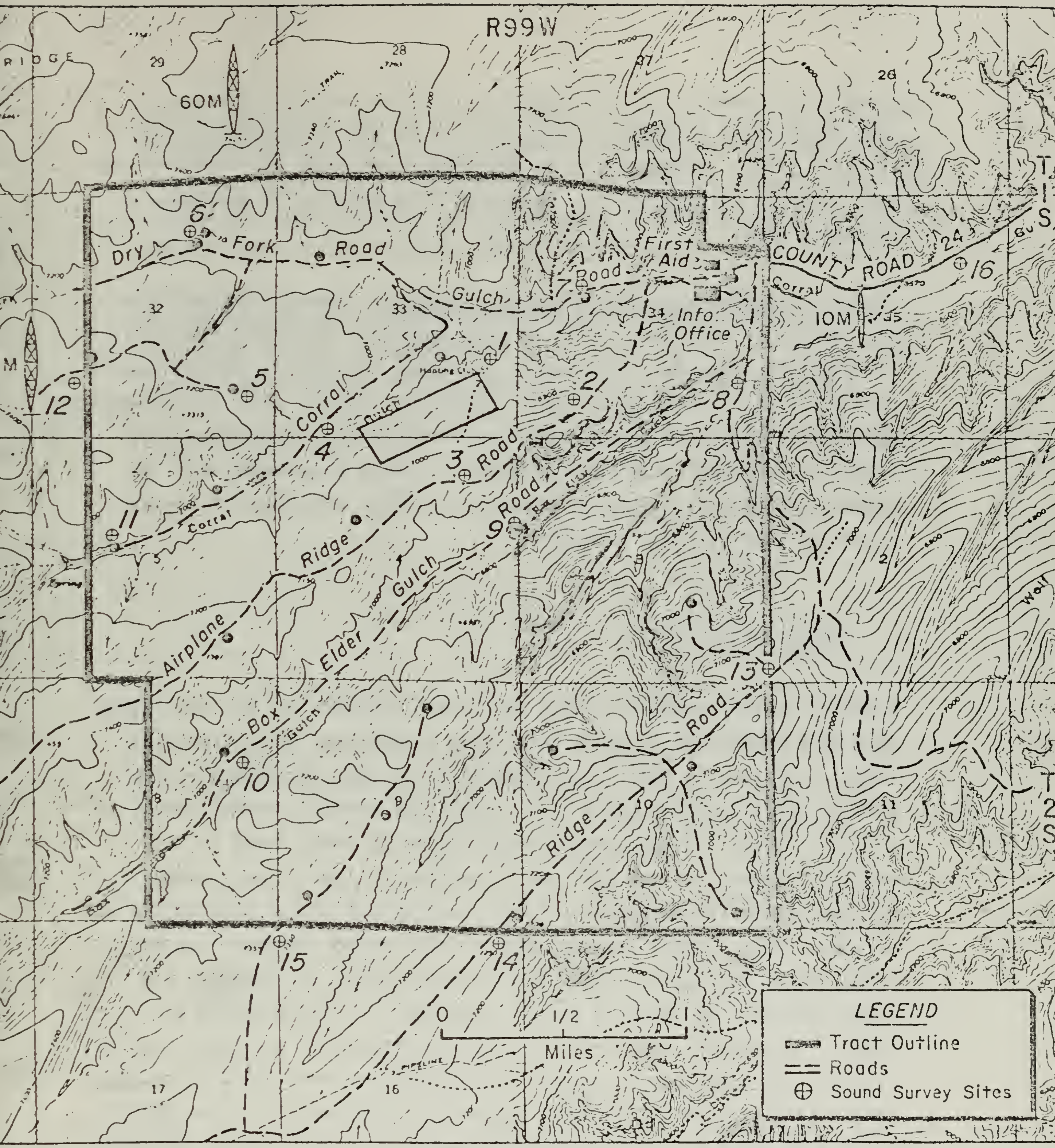



Figure 3.1. Environmental Sound Level Monitoring Sites

Sound level readings will be reported as highest and lowest range for each of the five readings at each site and as the sound level average of all five sites. Averages will be determined by adding all 10 values for each site and dividing by 10. Values will be reported in decibels, A weighting (dBA).

3. Experimental Design and Data Analysis - Sound data collected as a result of this survey will be made available to wildlife biologists studying the tract for their use in assessing the impacts of development on the wildlife in the area. This information will be used in conjunction with activity data to assess long-term trends in deer use, song-bird densities and other population paramters. These assessments will be largely judgemental in nature since the data are not quantitative and cannot be statistically assessed.

## C. Modeling Studies

Modeling studies consistent with the latest planning for MDP facilities have been completed. Despite reductions of emission rates placing latest estimates at one-fifth to one-sixth of those presented in the Revised Detailed Development Plan, calculated ambient concentrations on an annual basis are approximately equivalent to those found in the modeling studies for the RDDP and calculated 24- and 3-hour average concentrations are found to be from 7 to 15 times higher than during the previous study. These findings result from several factors. In the latest plans the stack heights for the incinerator and scrubber are lower, the mass of effluent gas is lower and exit temperatures are lower. As a result the predicted rates of dispersion are lower than was true for the RDDP case. A second factor of major importance is the use of the straightline CRSTER model rather than the advection type NUSPUF model used previously to calculate 24-hour and 3-hour average concentrations. With the shorter stack heights impacts occur much closer to the source and sufficiently detailed meteorology is not available to drive the more rigorous model. Consequently, the approximate order of magnitude reduction in short-term ambient concentrations over that calculated from a straightline model is not realized in these studies because the effects occur relatively much closer to the source.

During the MDP period CRSTER model results will be compared against monitored ambient concentrations on an annual basis. If appropriate similar calculations will be carried out with the NUSPUF model.

## 4.0 TERRESTRIAL STUDIES

The RBOSC MDP terrestrial monitoring program is based on the results of the intensive two-year baseline program conducted for 1974 - 1976 and a detailed assessment of the terrestrial impacts expected to result from oil shale development on Tract C-a. The terrestrial baseline program was conducted on Tract C-a and the area within five miles of the tract boundary and included detailed soils, vegetation, and wildlife studies. A complete discussion of the results and interpretation of the terrestrial baseline program is presented in the Final Environmental Baseline Report (FEBR 1977).

The analyses performed on the Tract C-a terrestrial baseline data (FEBR 1977) suggest a high degree of heterogeneity within the soil and vegetation systems. Cluster analysis of soil characteristics indicated that 85 percent of the sample sites were similar but the principal component analysis of soil parameters indicated that one or two soil traits cannot be isolated as indicator or control factors. Soil properties selected for MDP monitoring were chosen as a result of "cause/effect" and "measurability" matrix analyses discussed in the RBOSC Revised Detailed Development Plan (RBOSC 1977).

The eight vegetation types studied during the baseline period exhibited an inherent complexity and variability between sampling locations. Community coefficient and percentage similarity measures were analyzed to determine the effort required to adequately sample vegetation for the monitoring program.

Major faunal elements surveyed included small mammals, large mammals, mammalian predators, avifauna, reptiles and amphibians, and invertebrates. These faunal groups were analyzed with respect to species composition, abundance of individuals, species diversity, and seasonal variation in composition, abundance and diversity. Of the faunal groups surveyed, the small mammals, avifauna, and large mammals are most important; the other three groups have been excluded from the monitoring program due to their limited presence on the Tract C-a study area or the inability to adequately assess their numbers. Although the habitats and associated fauna on Tract C-a are ecologically important, they are not unlike other portions of the Piceance Basin.

An assessment by means of a "cause/effect" matrix analyses was conducted to determine impacts expected to result from oil shale development on Tract C-a. All known proposed actions affecting environmental parameters were considered. The more important interactions were found to be:

<u>Soils</u>
- Retorting on Chemical Characteristics
- Cumulative Construction on Erosion Potential
- Power Plant Cooling on Chemical Characteristics
- Waste Disposal on Physical and Chemical Characteristics

<u>Vegetation</u>
- Dewatering and Subsequent Discharge on Distribution and Abundance
- Cumulative Construction on Distribution and Abundance
- Surface Retorting on Trace Metal Content
- Processed and Raw Shale Disposal on Distribution, Abundance, and Trace Metal Content

<u>Wildlife</u>
- Cumulative Construction on Distribution and Abundance
- Dewatering on Large Mammal and Avifauna Distribution and Abundance
- Manpower on Large Mammal, Predatory Mammal, and Avifauna Distribution and Abundance
- Cumulative Waste Disposal on Avifauna Distribution and Abundance

Environmental parameters which are either expected to be affected by developmental activities or are ecologically or politically important have been included in the terrestrial monitoring program.

## 4.1 ABIOTIC MONITORING

### A. Soils

Analyses of the baseline soils data indicated that soil traits which can be identified as "indicators" cannot be verified for Tract C-a and the vicinity. Soils do, however, represent a secondary transport medium in the ecosystem, being the major contributor of chemical constituents for uptake by both plants and animals. For this reason impacts on the soil stratum need to be identified and quantified to the highest degree possible. Changes in trace metal content and conductivity levels are the most probable impacts of development that can be measured with a reasonable degree of accuracy. Dispersion of particulate matter from stacks and salt drift from cooling towers may result in discernible changes in soil trace metal content and conductivity.

Recent modeling efforts have been completed using stack heights now anticipated for the MDP. These studies indicate that dispersion of 11 lb/hr of particulate matter from the MDP stacks will result in maximum annual ground level particulate concentrations of 0.48 $ug/m^3$. Maximum 24-hour ground level particulate concentration will be 6.9 $ug/m^3$. Both these values are well within primary and secondary National Ambient Air Quality Standards.

No new data are available for salt drift. However, analyses completed during 1977 indicated that salt deposition could be as high as 500 $g/m^2$ in the immediate vicinity of the cooling tower decreasing to 0.5 $g/m^2$ at the tract boundaries.

1. Trace Metal Accumulation -

a. Objectives - The prime objective of the trace metal accumulation study is to determine if releases of particulate matter from operations on tract have appreciably affected the concentration of these metals in soils of the area. The second objective is to determine if metals accumulated in soils have been taken up by plants.

b. Methods - Particulate releases ( 11 lb/hr) during the MDP will be quite low and maximum concentrations are not expected to be sufficient to affect the soil stratum. However, accumulation over several years may result in measureable increases in these constituents. Therefore, the following study is proposed.

Soil and vegetation samples will be collected prior to the first retort burn (1979) and stored. Samples will be collected annually (August) thereafter and stored. Concurrently, stack sampling of emissions will be carried out. Analyses of stored samples will take place under the following circumstances: 1) after the burn of Retort 5 to test for long-term accumulation or 2) immediately if stack sampling data indicate that trace metals have escaped from the stacks in sufficient quantities to cause concern.

If analysis of the samples taken after the burn of Retort 5 does not reveal a significant increase in trace metal content of affected area soils over the control area soils, no further analysis of stored samples will be carried out. However, if significant increases are verified, then samples will be analyzed in decreasing order by age to determine the rate of increase by year. Baseline data for trace metals in Tract C-a soils revealed a great deal of variability indicating that data for specific baseline sample sites may not be suitable for use in comparison with samples taken from control and impact sites throughout the MDP. Therefore, suitability of existing baseline data for such comparisons will be determined when MDP samples are collected. Suitability will be based on similarity of soil types, proximity of locations and variability among specific samples. If adequate confidence limits cannot be established from these data, then soil samples collected from the control and impact sites (Figure 4.1) prior to the first retort burn will be used to provide additional baseline data for trace metal studies.

Two control and two impact (treatment) sites will be selected for sample collection (Figure 4.1). Control sites will be placed to the northeast and southeast of the tract, outside potential dispersion patterns. The impact site will be located northwest and southwest of the emission sources in areas of predicted maximum short-term and annual concentrations. The sampling locations will be of sufficient size to assure thorough coverage of the potential impact zones. Locations of sampling sites will be re-evaluated periodically on the basis of modeling data and source locations. If necessary, the sites will be relocated.

Ten soil samples will be collected during August of each year from the surface soils (0-10 cm) of each site. Five composite vegetative samples each, of sagebrush and a metal-concentrating plant, e.g., Astragalus, will be collected at each site from the current year's growth (Table 4.1).

If significant levels of trace metals are released from stacks, then soil samples will be immediately analyzed for those elements identified in the emissions, e.g., Sb, As, B, Cd, F, Hg, Se, Mo, and V. If trace metal levels in the impact site soil samples are shown to be significantly greater than levels which were present during the baseline studies, or levels present in the control samples, then vegetation samples will be analyzed to determine if trace metals have been taken up into the food chain.

The soils and vegetation trace metal accumulation data will be entered and stored on 9-track, 800 bpi magnetic tape according to documented quality assurance procedures.

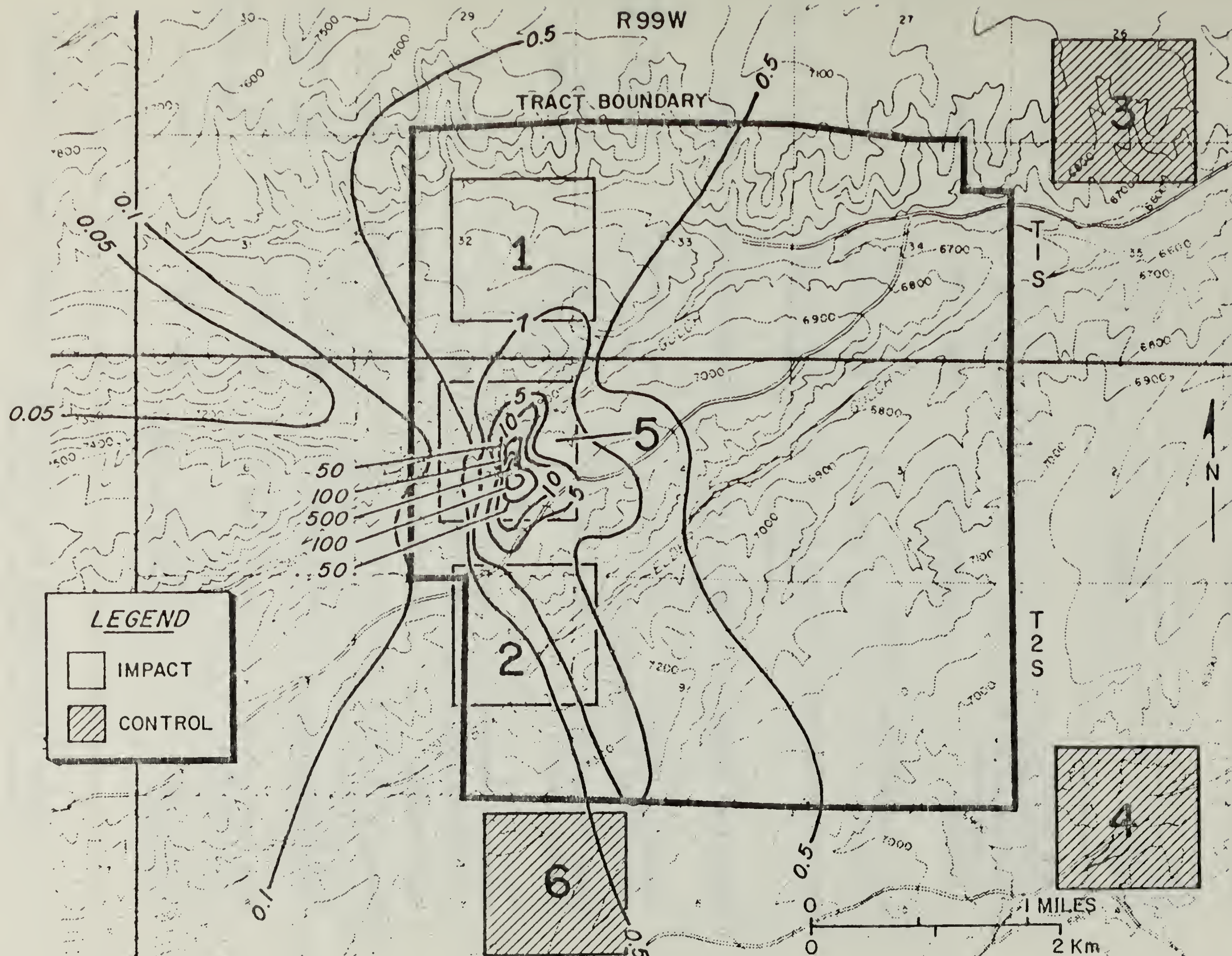



Figure 4.1. Tentative locations of soil sampling sites; 1-4 trace metal accumulation sites; 5-6 conductivity sampling sites. Isopleths represent predicted pattern of salt disposition from cooling towers (g/m$^2$).

Table 4.1. Terrestrial Studies Monitoring Schedule

| Parameter | Location | Start Date | Frequency |
|---|---|---|---|
| Trace Metals (Collection & Storage of soils & vegetation samples) | NE,NW,SE,SW of Tract Corners | Aug. 1979 | Annually |
| Soil Conductivity Studies | See Figure 4.1 | Aug. 1981 | Annually |
| Vegetation Mapping | Tract C-a & 5-mile Perimeter | Aug. 1978 * | Every 3rd year |
| Vegetation Stress | Anticipated impact areas | June-July 1979 | Annually |
| Vegetation Phytosociological Studies | See Figure 4.1 | May-June 1979 | Once/3-yr perioc Rotation Basis |
| Range Productivity & Utilization | See Figure 4.2 | April 1978 (establish plots) | Annually (in Sept.) |
| Browse Condition & Utilization | See Figure 4.2 | May 1978 | Annually |
| Small Mammals | See Figure 4.1 | May-June 1979 | Annually |
| Avifauna Studies | See Figure 4.1 | May-June 1979 | Annually |
| Mule Deer Density Studies | See Figure 4.3 | Sept. 1977 | Semi-annually (May, Sept.) |
| Mule Deer - Road Kill Studies | County Road 24 | Feb. 1979 | Weekly During Peak Migratio |
| Feral Horse Abundance | Tract C-a & 3-mile Perimeter | Jan. 1978 | Annually |

* 1978 aerial photography was accomplished in August; however, subsequent flights will be scheduled for June-July

c. Experimental Design and Data Analyses - The trace metal study is designed to test the following hypothesis:

$H_0$: There are no significant differences in trace metal concentrations in soils sampled from four locations adjacent to Tract C-a before and during development.

Data on the trace metal concentration of soils collected from two locations are analyzed by the following analysis of variance (ANOVA) design.

| | Source of Variation | Degrees of Freedom | F-Test |
|---|---|---|---|
| A. | Location a = 4 | a-1 = 3 | A/B |
| B. | Sampling sites within locations $b_i$ = 10 | $a(b_i-1) = 36$ | B/F |
| C. | Phase c = 2 | c-1 = 1 | C/F |
| D. | Location x Phase | (a-1)(c-1) = 3 | D/F |
| E. | Sampling sites within location x Phase | $a(b_i-1)(c-1) = 36$ | E/F |
| F. | Error (n=2) | $ab_ic(n-1) = 40$ | |
| | Total | 159 | |

This partial hierarchical ANOVA design (Kirk 1968) is used to determine the difference in soil trace metal concentrations between locations (main effect A), before versus during development (main effect C), and in the nested effect (B) will test differences among sampling sites within locations. The interaction effects (D and E) will test location x phase and samples within location x phase. If the interaction effect is significant, then a multiple range test will be performed to determine the source of significant interactions.

If significant differences between phases are detected, then the vegetation analyses will be initiated as well as an interaction analysis between trace metal content in soils versus trace metal content in vegetation.

The trace metal vegetation study is designed to test the hypothesis:

> $H_0$: There are no significant differences in trace metal concentrations in two plant species sampled from four locations near Tract C-a before and during development.

Data collected from four locations on the trace metal concentration of the two plant species (sagebrush and a metal-concentrating plant, e.g., Astragalus) will be analyzed by the following ANOVA design.

| | Source of Variation | Degrees of Freedom | F-Test |
|---|---|---|---|
| A. | Location a = 4 | a-1 = 3 | A/H |
| B. | Phase b = 2 | b-1 = 1 | B/H |
| C. | Species c = 2 | c-1 = 1 | C/H |
| D. | Location x Phase | (a-1)(b-1) = 3 | D/H |
| E. | Location x Species | (a-1)(c-1) = 3 | E/H |
| F. | Phase x Species | (b-1)(c-1) = 1 | F/H |
| G. | Location x Phase x Species | (a-1)(b-1) (c-1) = 3 | G/H |
| H. | Error (n = 5) | abc(n-1) = 64 | |
| | Total | abcn - 1 = 79 | |

This three-way ANOVA will be used to determine differences among four locations (main effect A), between phases (main effect B), and between plant species (main effect C). First order interactions include differences in locations by phase (D), differences between species within locations (E), and differences between species by phase (F). Second order interactions will examine trace metal concentrations by location, phase, and species (G). Significant effects will be examined with multiple range tests to identify the source of the interaction.

2. Soil Conductivity Studies -

a. Objectives - Concentrations of salt drift from cooling towers are projected to be low; nevertheless, the soil studies are designed to detect any significant changes in soil salinity or conductivity levels which may be detrimental to plant growth. The conductivity studies will not be triggered until just prior to the commercial phase, since the source of impact will not exist until that time.

b. Methods - Modeling efforts indicate that the maximum concentrations of salt drift are expected to occur immediately adjacent to the cooling tower (Figure 4.1). The areas of maximum deposition are limited to within the tract boundaries. Large deviations from the projected dispersion pattern are not expected because of the large size of the salt droplets. Therefore, specific control and impact sites (0.5 x 0.5 mile; Locations 5 and 6) have been selected in the expected maximum and minimum salt deposition areas (Figure 4.1).

The control site was selected in an area where soils (Rentsac and Rentsac-Piceance) are similar to those in the impact area. Baseline studies indicate that both soil series have low soil conductivities (Rentsac = 1.6 mmhos/cm; Piceance = 1.3 mmhos/cm based on a saturated paste sample). Therefore if appreciable salt deposition occurs, detection of a change in soil conductivity should be possible.

The conductivity control site was selected in an area which will also be the control site for other vegetation, small mammal and avifauna studies. The multiple use of this control site will permit analysis of interrelationships among soil, vegetation, and faunal parameters.

Twenty soil samples will be collected randomly from the Rentsac or Rentsac-Piceance soils in the control sites. Samples will be collected each August beginning in 1981, or the year prior to commercial development. Soil samples will be collected from the surface soils (0 to 10 cm) of each site. These samples will be analyzed by a commercial laboratory to determine electrical conductivity.

The soil material remaining after analysis will be stored. If a significant change in electrical conductivity is detected in samples after operation of the cooling towers begins, the stored samples will be analyzed to identify those elements contributing to the increased conductivity, e.g., chloride, gypsum, etc. In addition, if conductivity levels approach 6 mmhos/cm (medium salt tolerance) (U.S. Salinity Lab Staff 1954) then vegetation composition studies will be initiated.

Data are entered and stored on 9-track, 800 bpi magnetic tape according to documented quality assurance procedures.

c. Experimental design and data analyses - The soil conductivity studies are designed to test the following hypotheses.

$H_0$: There is no significant difference in the soil conductivity between the control and impact sites before development; during development.

$H_0$: There is no significant difference in soil conductivity at the impact site before and during development; at the control site before and during development.

Soil conductivity data collected from two locations (impact and control sites) are analyzed by the following ANOVA:

| | Source of Variation | Degrees of Freedom | F-Test |
|---|---|---|---|
| A. | Location a = 2 | a-1 = 1 | A/D |
| B. | Phase b = 2 | b-1 = 1 | B/D |
| C. | Location x Phase | (a-1)(b-1) = 1 | C/D |
| D. | Error (n = 20) | ab(n-1) = 76 | |
| | Total | abn - 1 = 79 | |

This two-way ANOVA design is used to determine the differences in soil conductivity between two locations (main effect A) and between phases (before versus during development, main effect B). The interaction effect (C) will test location x phase interactions. If the interaction effect is significant, then multiple range tests will be performed to determine the source of the interaction. If significant differences between phases are detected, then interaction correlations will be conducted as described in greater detail in the interactions section of this scope.

## 4.2. BIOTIC MONITORING

### A. Vegetation

Detection and evaluation of impacts on vegetation is anticipated to be difficult due to the heterogeneity found in the vegetation types on Tract C-a as discovered during the baseline studies. Analyses of plant species composition (community coefficient) and plant species abundance (percentage similarity) indicate a high degree of complexity and variability between locations sampled during the baseline studies. Such inherent variability makes it difficult to separate normal annual fluctuations from those caused by oil shale development. Therefore, the vegetation program includes the following studies in order to facilitate interpretation of the data:

- Vegetation Type Distribution
- Phytosociological Studies Including Photoplot Monitoring
- Range Productivity and Utilization
- Browse Condition and Utilization

These studies were also selected since they will be useful in detection of any changes anticipated to result from construction, dewatering, or waste disposal as indicated by the detailed impact assessment, i.e., matrix analysis, conducted by RBOSC.

1. Vegetation Type Distribution -

a. Objectives - Construction and operation at Tract C-a may affect the local distribution of vegetation. This study is designed to monitor the distribution of vegetation in the tract vicinity and to detect any large-scale changes in the distribution of vegetation types resulting from Tract C-a development. This qualitative program permits RBOSC to monitor Tract C-a and the surrounding area on a large scale to determine if impacts not previously predicted are occurring. If such impacts occur, then quantitative programs will be designed to determine the nature and extent of the detected impact.

b. Methods - Color aerial photography (1 inch = 2,000 feet scale) will be taken at three-year intervals, with the photographed area including Tract C-a and the area within a five-mile radius. These photographs will be compared to the RBOSC vegetation map (RBOSP 1977) and earlier color aerial photographs to determine any changes in the distribution of vegetation types. If changes are detected, the vegetation map will be modified to reflect them. Color aerial photography are available for 1974 and 1978.

Color infrared (CIR) aerial photography (1 inch = 660 feet scale) will be taken on an annual basis to determine major vegetation stress conditions.

If stress conditions are identified, an additional sampling program will be initiated upon approval by AOSO to determine the extent and cause of damage. CIR Photography will include those portions of the region where appreciable concentrations of harmful air pollutants have been predicted by air plume models, where dewatering has caused depression of the upper aquifer, or where surface water has been affected. Such areas will be determined in cooperation with the AOSO. CIR aerial photography will begin in June - July 1979.

Ground control points will be established prior to 1979 flights so as to better locate photographs relative to ground features.

c. Experimental design and data analyses - This program is designed to provide qualitative information on vegetation distribution since statistical analyses are not appropriate. Vegetation distribution data are presented on a vegetation map which is used as the basis for calculating by planimetry the acreage of each vegetation type in the study area. Vegetation distribution is compared between years to determine the extent of any potential changes in habitat resulting from Tract C-a development. These data are not computer compatible and are not stored on computer tape.

2. Phytosociological Studies

a. Objectives - The objective of the vegetation phytosociological studies is to monitor species composition and cover in the major vegetation types expected to be affected by oil shale development. Such information will provide quantitative data which will complement the vegetation type distribution information for major habitat types and provide continuity with similar information collected during the baseline period. Additional monitoring records will include photoplots.

b. Methods - Phytosociological studies will provide data on the following parameters:

- Species Composition
- Cover (%)
- Density of Woody Species

Phytosociological studies will be conducted in pinyon-juniper and sagebrush vegetation types in a control site south of Tract C-a (Location 6) and in a treatment site on Airplane Ridge (Location 5) (Figure 4.1). These sites correspond to the sampling locations for the soil, small mammal, and avifauna studies. As development progresses the treatment site will be moved as necessary.

Phytosociological sampling will be conducted in May-June once every three years in a specific vegetation type on a rotation basis. During the initial sampling period in each type, density and cover of woody species and herbaceous cover wil be determined; thereafter only herbaceous cover will be measured. Sampling will begin in May - June 1979 in the pinyon-juniper habitat type.

Density of woody species will be determined in five permanently established belt transects (100x6m). This modified line-strip method was used to determine density of woody species during the baseline program (RBOSC 1975). In addition, a line-transect (100m length) will be established in each of the five belt transects (total 500m) to determine cover of each woody species.

Herbaceous cover will be measured within 20 1x1m plots permanently established within each belt transect (total 100 plots per vegetation type).

At each control and treatment site within each vegetation type, photoplots will be established at each belt transect to monitor changes in the vegetation. Photos will be taken annually during May from permanently marked locations.

Cover and density data will be entered and stored on 9-track, 800 bpi magnetic tape and all data analyses are performed by computer. Methods follow standard quality assurance procedures.

c. Experimental Design and Data Analysis - The phytosociological studies are designed to test the following hypothesis:

$H_o$: There is no significant difference in herbaceous cover within a vegetation type before and during modular development.

The herbaceous cover data are analyzed by the following ANOVA to compare pre-development conditions with those during development.

| Source of Variation | Degrees of Freedom | F-Test |
|---|---|---|
| A. Location a=2 | a-1 = 1 | A/D |
| B. Phase b=2 | b-1 = 1 | B/D |
| C. Location x Phase | (a-1)(b-1) = 1 | C/D |
| D. Error (n=100) | ab(m-1) = 396 | |
| Total | abn-1 = 399 | |

This two-way ANOVA design is used to determine the differences in herbaceous cover between two locations (main effect A) and between phases (before versus during development, main effect B). The interaction effect (C) will test location x phase interactions. If the interaction effect is significant, then multiple range tests will be performed to determine the source of the interaction.

Because the woody species data will be collected once, these data are not amenable to ANOVA analyses. These data will serve as additional "baseline" information for the control and treatment sampling sites and will be used in the interactions analyses with the wildlife data. If impacts are detected by the photoplot or vegetation distribution monitoring programs, then subsequent woody species sampling programs will be initiated.

3. Range Productivity and Utilization

a. Objectives - The Modular Development Phase (MDP) activities on Tract C-a may affect the range conditions in the vicinity of the tract. These studies are designed to provide information on vegetative production which can be used to compare range productivity before and during modular development. Range utilization will be determined although this parameter cannot be used as an impact indicator since it is affected by stocking rates. Because the potential impacts are projected to be local, the range studies focus on areas on Tract C-a that are adjacent to MDP activities and that were previously used for grazing.

b. Methods - The range sampling sites were selected at random in mixed brush, pinyon-juniper, and sagebrush in the same general location as the browse transects. The distribution of the interim range transects (mixed brush-5, pinyon-juniper-10, sagebrush-15) were modified to establish 10 transects in each vegetation type. The five transects located on 84 Mesa during the interim program will not be sampled during the MDP. The locations of the 30 range sampling transects are presented in Figure 4.2. Plots 31 through 39 are in different locations from the interim locations established for the MDP monitoring. Because transects 5, 11 and 12 are located in close proximity to the MDP activities, these transects may be relocated to adjacent areas as development progresses.

Forage is measured annually at the end of the growing season (September) (Table 4.1) by the double sampling method (USDA Region 2 1970).

An adequate sampling size, based on present total herbaceous cover, was determined for each vegetation type. These estimates were calculated for each of the six sampling periods in 1975 and 1976 (FEBR 1977). Based on 1.0 x 0.5 m quadrats, an adequate sampling size (detection of ±10% of the mean 90% of the time) is 302 sample quadrats for mixed brush, 383 for pinyon-juniper, and 403 for sagebrush. However, the

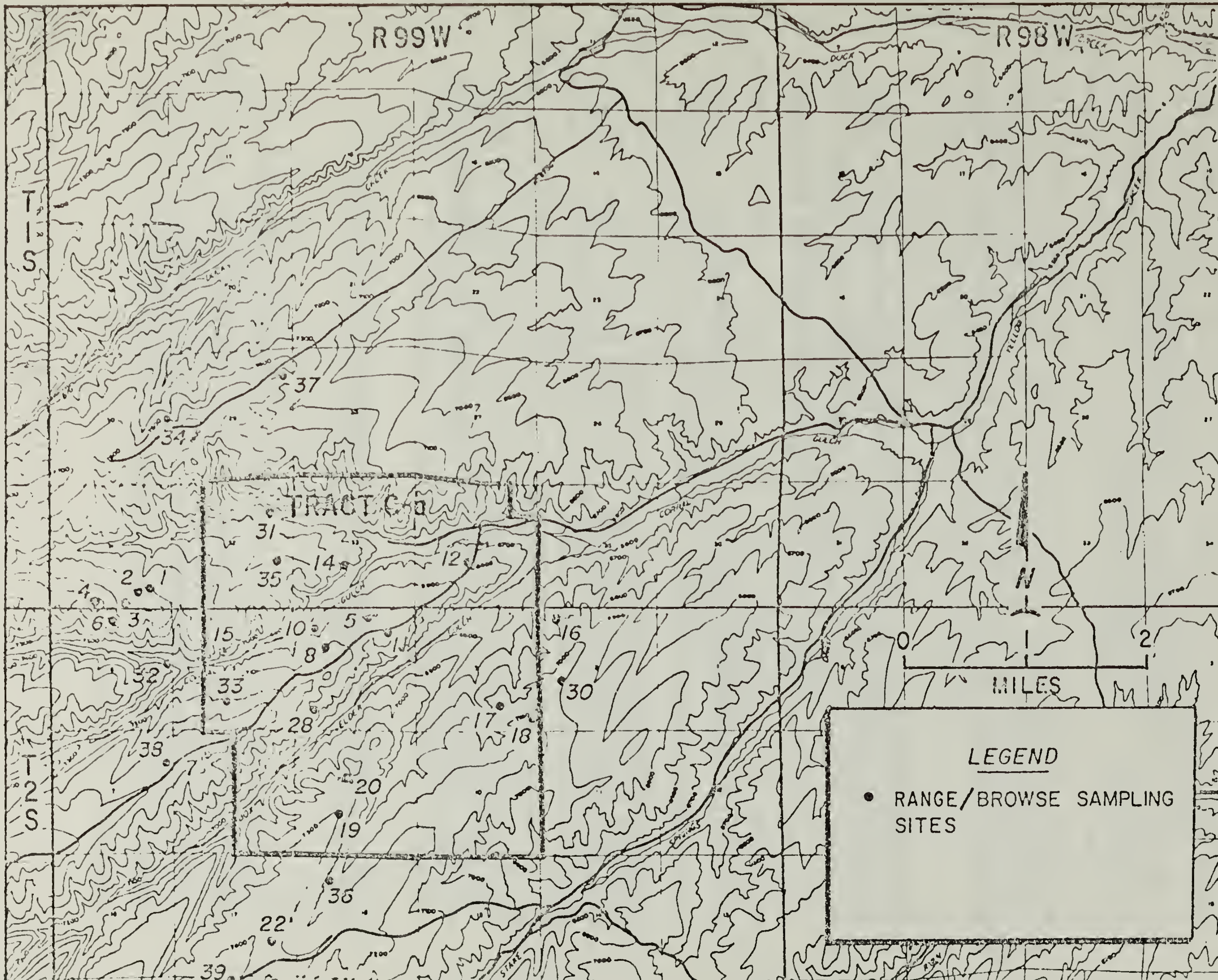



Figure 4.2. Locations of MDP Range/Browse Sampling Sites.

extremely high number of sample quadrats required for this level of detection is not practical or feasible for development monitoring. Sample size requirements to detect a difference of ± 25% of the mean 90% of the time, are 64 for sagebrush, 49 for mixed brush, and 61 for pinyon-juniper. The range productivity and utilization studies are designed to include 10 transects per vegetation type (10 plots/transect) or a total of 100 plots. This sampling intensity should detect a difference of ± 25% of the mean 90% of the time. The sampling intensity will be evaluated after the first year and the program modified as necessary.

Five caged plots (9.6 sq. ft. in size), and five unprotected plots (permanently marked) are located at 10-m intervals along each sample transect. The plots are permanently established in April of the first year, and the five caged plots are moved to new locations each April-May (Table 4.1). Sampling is done with a 9.6 sq. ft. sampling loop on each of five unprotected plots. An ocular estimate is made of production (weight to the nearest gram) of the dominant grass and forb species (species making up 90 percent of the individuals) within the loop. The five protected plots are estimated in the same manner. Each species within the protected plots is then clipped, bagged separately, weighed green, and the weights are recorded. Species providing less than one percent of the biomass are recorded as being present, but are not weighed. Correction factors are calculated from the estimated green weights and actual green weights of the clipped plots.

$$\text{CORRECTION FACTOR} = \frac{\text{Actual Green Weight}}{\text{Estimated Green Weight}}$$

These correction factors will be used to correct all estimated values. Clipped samples will be air-dried for approximately 30 days and weighed to obtain moisture percentages. All corrected estimates will then be computed, using these moisture percentages to obtain air-dry forage productivity estimates.

Utilization is calculated as follows:

$$\text{Utilization} = \frac{\text{Average productivity per ungrazed plot} \times \text{Average productivity per grazed plot}}{\text{Average productivity per ungrazed plot}} \times 100$$

Damage from insects or frost is qualitatively assessed. Any damage is recorded and an estimate of damaged vegetation is made to determine the percent of the sampled vegetation which is affected.

Data are entered and stored on 9-track, 800 bpi magnetic tape and all data analyses are performed by computer. Data are handled according to documented quality assurance procedures.

c. Experimental design and data analyses - The range studies are designed to test the following hypothesis:

$H_o$: There is no significant difference in vegetative productivity within a vegetation type before and during modular development.

The range productivity data are analyzed by the following ANOVA to compare pre-development conditions with those during development.

| | Source of Variation | Degrees of Freedom | F-Test |
|---|---|---|---|
| A. | Phase a = 2 | a-1 = 1 | A/D |
| B. | Protected vs. Unprotected Plots b = 2 | b-1 = 1 | B/D |
| C. | Phase x Plots | (a-1)(b-1) = 1 | C/D |
| D. | Error (n = 50) | ab(n-1) = 196 | |
| | Total | abn - 1 = 199 | |

The two-way ANOVA design is used to determine the difference in primary production between phases (main effect A) and between protected and unprotected plots (main effect B). Differences are expected between protected and unprotected plots as a result of grazing. The first order interaction examines differences in plots by phase which will indicate if protected versus unprotected areas respond similarly to modular oil shale activities over time.

Range utilization data will be used as an indicator of grazing pressure in the tract vicinity. These data will not be analyzed by the above ANOVA since significant differences between phases would not be indicative of impacts resulting from oil shale development.

4. Browse Condition and Utilization

a. Objectives - Tract C-a development may reduce browse availability and therefore affect animal distribution in the vicinity of Tract C-a. The browse condition and utilization studies are designed to provide browse use information for areas adjacent to Tract C-a development.

b. Methods - Browse condition and utilization are measured along 30 transects (mixed brush-10; pinyon-juniper-10, sagebrush-10). The browse transects are located in the same general vicinity as the range transects (Figure 4.2).

Browse sampling is conducted annually in early May after deer have migrated through the Tract C-a area (Table 4.1).

Browse condition and utilization is estimated along transects consisting of 25 individual shrubs (Cole 1963). Transects are selected at random within each vegetation type.

Browse species sampled include: juniper (*Juniperus osteosperma*), pinyon (*Pinus edulis*), antelope bitterbrush (*Purshia tridentata*), snowberry (*Symphoricarpos oreophilus*), big sagebrush (*Artemisia tridentata*), and true mountain mahogany (*Cercocarpus montanus*).

During field sampling, five parameters are examined and recorded including:

Form classes:

1. All available, little or no hedging
2. All available, moderately hedged
3. All available, severely hedged
4. Partially available, little or no hedging
5. Partially available, moderately hedged
6. Partially available, severely hedged
7. Unavailable
8. Dead

Age Classes:

S - seedling - less than 0.3 cm basal diameter

Y - young - 0.3 to 0.6 cm basal diameter

M - mature - over 0.6 cm basal diameter

D - decadent - more than 25 percent of crown surface is dead

Leader Use Estimates:

Percent of twigs or leaders which are available and show use

Hedging Classification:

Classification based upon the length and appearance (hedging) of the previous year's growth (the two-year old wood):

1. None to light
2. Moderate
3. Severe

Availability:

Visual estimate of the percent of the plant available to deer as browse, i.e., that portion less than six feet high.

Damage from insects or frost is assessed qualitatively. Any damage is recorded and an estimate of damaged vegetation is calculated to determine the percent of the sampled vegetation which is affected.

Data are entered and stored on 9-track 800 bpi, magnetic tape and all data analyses are performed by computer. Data control procedures are outlined in the Quality Assurance Manual.

c. Experimental design and data analyses - The browse studies are designed to test the following hypothesis:

$H_0$: There is no significant difference in browse utilization of a specific plant species within a given vegetation type before and during development.

The browse utilization data collected in the mixed brush, pinyon-juniper and sagebrush types are analyzed by the following ANOVA. Percentage data are transformed to arc sines (Sokal & Rohlf 1969) prior to statistical analyses.

| | Source of Variation | Degrees of Freedom | F-Test |
|---|---|---|---|
| A. | Phase of development $a = 2$ | $a-1$ | A/B |
| B. | Number of individuals/species within 10 transects $b_i = x$ | $a(b_i-1)$ | B/C |
| C. | Error ($n = 10$) | $a(b_i)(n-1)$ | |
| | Total | $ab_in-1$ | |

This nested ANOVA is used to compare differences in browse use for a specific plant species within a vegetation type before versus during development (main effect A) and among individuals within each plant species for a developmental phase (nested effect B).

Browse utilization data collected during the first year will be used to verify the number of transects necessary to detect a difference of $\pm$25% of the mean 90% of the time; the sampling intensity will be adjusted to achieve this detection level.

The browse condition data are class data which are not appropriate for ANOVA techniques. These data are summarized and qualitatively compared between years.

B. Fauna

The faunal elements expected to be most affected by oil shale activities include small mammals, avifauna, and large mammals. Of these three groups, large mammals are also politically sensitive due to the status of the Piceance Creek deer herd and its important recreational value in western Colorado. Matrix analysis indicated that the abundance and distribution of these elements are most likely to be affected. Therefore the following programs have been designed to monitor population parameters in important habitats on Tract C-a.

1. Small Mammal Studies - Intensive reviews of baseline data indicate that reliable small mammal population data such as density, age structure, and species diversity are difficult and costly to obtain; given reliable data, there is little agreement in the literature about the interpretation of even gross changes in population parameters (Snyder, 1978). The baseline data program will, therefore, be discontinued in favor of a limited program that is designed to determine species presence and habitat affinity and to provide indices of relative abundance in important control and treatment habits.

a. <u>Objectives</u> - To determine the presence and relative abundance (captures/trap night) of small mammals in sagebrush and pinyon-juniper habitats in control and treatment areas.

b. <u>Methods</u> - Parameters to be measured include:

- Species Presence
- Relative Abundance

Small mammals will be monitored in pinyon-juniper and sagebrush habitat types in a control area (6) just south of the tract boundary near air studies site 2 and in a treatment site 5 on Airplane Ridge near site activities through 1981 (Figure 4.1). As development progresses the treatment site will be moved as necessary.

Small mammals will be sampled annually during May - June beginning in 1979.

Three to five transects will be placed in each habitat type for each area. Each transect will consist of two lines of ten Sherman live traps; lines and traps will be 15 meters apart. Bait will consist of a mixture of peanut butter and seeds.

Sampling will be conducted in late spring - early summer for three to four consecutive days. Traps will be identified to species, sexed, aged, marked and released.

The statistical detection level for this sampling intensity is a function of the number of captures; as captures increase the confidence interval will narrow. It is not possible to predict detection levels *a priori* since capture numbers are not controllable.

Data are entered and stored on 9-track, 800 bpi magnetic tape according to established quality assurance procedures.

c. Experimental Design and Data Analyses - The small mammal data will be presented as relative abundance (captures per trap night) in sagebrush and pinyon-juniper habitats in the control and treatment areas. For each year of the program and for each habitat type, species found in both the control and treatment area will be ranked according to their relative abundance; Spearman's Rank Correlation Coefficient will then be calculated to determine the degree of relationship between the control and treatment data. Coefficients of rank correlation will be compared between years to determine if the relative abundance of small mammal species has changed as site development progresses.

The between year data will be used to test the hypothesis:

$H_0$: There is no significant difference in the rankings of the relative abundance of small mammal species on control and treatment areas within each habitat type when rankings are compared between years.

Interpretations of the small mammal data will be constrained in several ways. The coefficients of rank correlation provide an indication of a relationship in the relative abundance rankings of species in the control and treatment areas; there is no obvious rationale to explain the degree of relationship other than the expectation that similar habitats should have similar small mammal populations.

Tests of the null hypothesis will indicate whether or not there are statistically significant differences in the coefficients of rank correlation between years; if the null hypothesis is rejected in the relative abundance rankings of small mammals on the control and treatment areas, these differences could be due to natural variation, "treatment effects", or sampling errors (e.g. differences in phenology between identical calendar dates during the two years). At best, the results of the small mammal sampling program will provide one of many qualitative program indices about possible effects of site development.

If significant differences between locations occur a detailed analyses of other parameters sampled in these two locations will be initiated. This analysis will indicate if these differences reflect natural fluctuations or are also evident in soil and/or vegetation elements. If it appears that oil shale activities are negatively affecting population levels, more detailed small mammal studies (e.g. fall sampling) will be initiated.

2. Avifauna Studies - Previous RBOSC avifauna studies on Tract C-a included determination of seasonal variations in songbird population composition, distribution and abundance during the baseline program and studies on selected species and parameters during the interim program. There is little, if any, evidence, however, that avifauna sampling programs that are conducted within reasonable constraints of time and money can detect any except gross changes in bird population parameters or any of many possible natural abiotic or biotic causes (Wiens, 1977). The avifauna program will, therefore, be designed to determine species composition and relative abundance in important control and treatment habitats.

a. Objectives - To determine species composition and relative abundance of birds in pinyon-juniper and sagebrush habitats in control and treatment areas.

b. Methods - Parameters to be measured include:

- Species Composition
- Relative Abundance

Avifauna will be monitored in pinyon-juniper and sagebrush habitats in a control area (6) south of the tract boundary and in a treatment site (5) on Airplane Ridge near site development activities (Figure 4.1). These control and treatment sites are the same plots being used for soil, phytosociological vegetation, , and small mammal studies. In addition, air studies Site 2 is located near the control area. The multiple sampling program at these two sites will permit future interrelationship analyses as described in Section 8.0

Avifauna studies are conducted annually during the breeding period each spring (May-June) beginning in 1979.

Avifauna are monitored by means of a modified Emlen transect method (Emlen 1971 and 1977). Two half-mile transects will be run in each habitat type in each area during the breeding season. Birds detected up to 200 feet from the transect line will be recorded. Each transect will be run three times during early morning hours.

The statistical detection level for this sampling intensity is a function of the number of bird observations; as observations increase the confidence interval will narrow. It is not possible to predict detection levels _a priori_ since observation numbers are not controlled by the observer.

Data are entered and stored on 9-track, 800 bpi magnetic tape according to established quality assurance procedures.

c. _Experimental Design and Data Analyses_ - The avifauna data will be presented as species composition and relative abundance (individuals of and bird species per total number of birds observed) for sagebrush and pinyon-juniper habitats in the control and treatment areas. For each year of the program and for each habitat type, species found in both the control and treatment area will be ranked according to their relative abundance; Spearman's Rank Correlation Coefficient will then be calculated to determine the degree of relationship between the control and treatment data. Coefficients of rank correlation will be compared between years to determine if the relative abundance of avifauna species has changed as site development progresses.

The between year data will be used to test the hypothesis:

> $H_0$: There is no significant difference in the rankings of the relative abundance areas within each habitat type when rankings are compared between years.

Interpretations of the bird data will be constrained in several ways. The coefficients of rank correlation provide an indication of a relationship in the relative abundance rankings of species in the control and treatment areas; there is no obvious rationale to explain the degree of relationship other than the expectation that similar habitats should have similar avifauna populations.

Tests of the null hypothesis will indicate whether or not there are statistically significant differences in the coefficients of rank correlation between years; if the null hypothesis is rejected it means only that there may have been differences in the relative abundance rankings of avifauna on the control and treatment areas. These differences could be due to natural variation, "treatment effects", or sampling errors (e.g. differences in phenology between identical calendar dates during the two years, sample sizes too small). At best, the results of the bird sampling program will provide one of many qualitative program indices about possible effects of site development.

If significant differences between locations occur, a detailed analysis of other parameters sampled in the two locations will be initiated. This analysis will indicate if these differences reflect natural fluctuations or are also evident in soil and/or vegetation elements. If it appears that oil shale activities are adversely affecting avifauna population levels, additional bird studies will be initiated.

3. Mule Deer Density

a. Objectives - Mule deer are the most important game species in Colorado in terms of recreational use and money expended by hunters. The Piceance Creek basin mule deer herd is one of the largest migratory mule deer herds in North America. Tract C-a is within Colorado Division of Wildlife's (CDOW) Game Management Unit 22 (Piceance).

Moderate numbers of mule deer occur on Tract C-a during migration periods, particularly spring, and during mild winters; at other times mule deer are relatively uncommon on the tract. Consideration of the possible effects of Tract C-a oil shale development on mule deer is an integral part of RBOSC's Fish and Wildlife Management Plan.

The objectives of RBOSC's mule deer monitoring program are to obtain an index of mule deer density in a 9 x 9 mile (81 sq. mile) study area centered on Tract C-a (Figure 4.3), to compare indices of mule deer density from the study area with those from Game Management Unit 22, and, if possible, to compare differences in mule deer densities within various portions of the study area.

b. Methods - Tract C-a is in the center of a 9x9 mile (81 sq mi) study area which is divided into blocks (3 x 3 miles or 9 sq mi each). Seven quarter sections (160 acres, 64 ha) have been randomly selected from each block.

Pellet-group counts are made twice a year, once in the Spring (May), and once in the Fall (September), to determine the number of pellet groups deposited in the summer and during the migration and wintering periods (Table 4.1). All pellet groups are removed from the plots as they are counted.

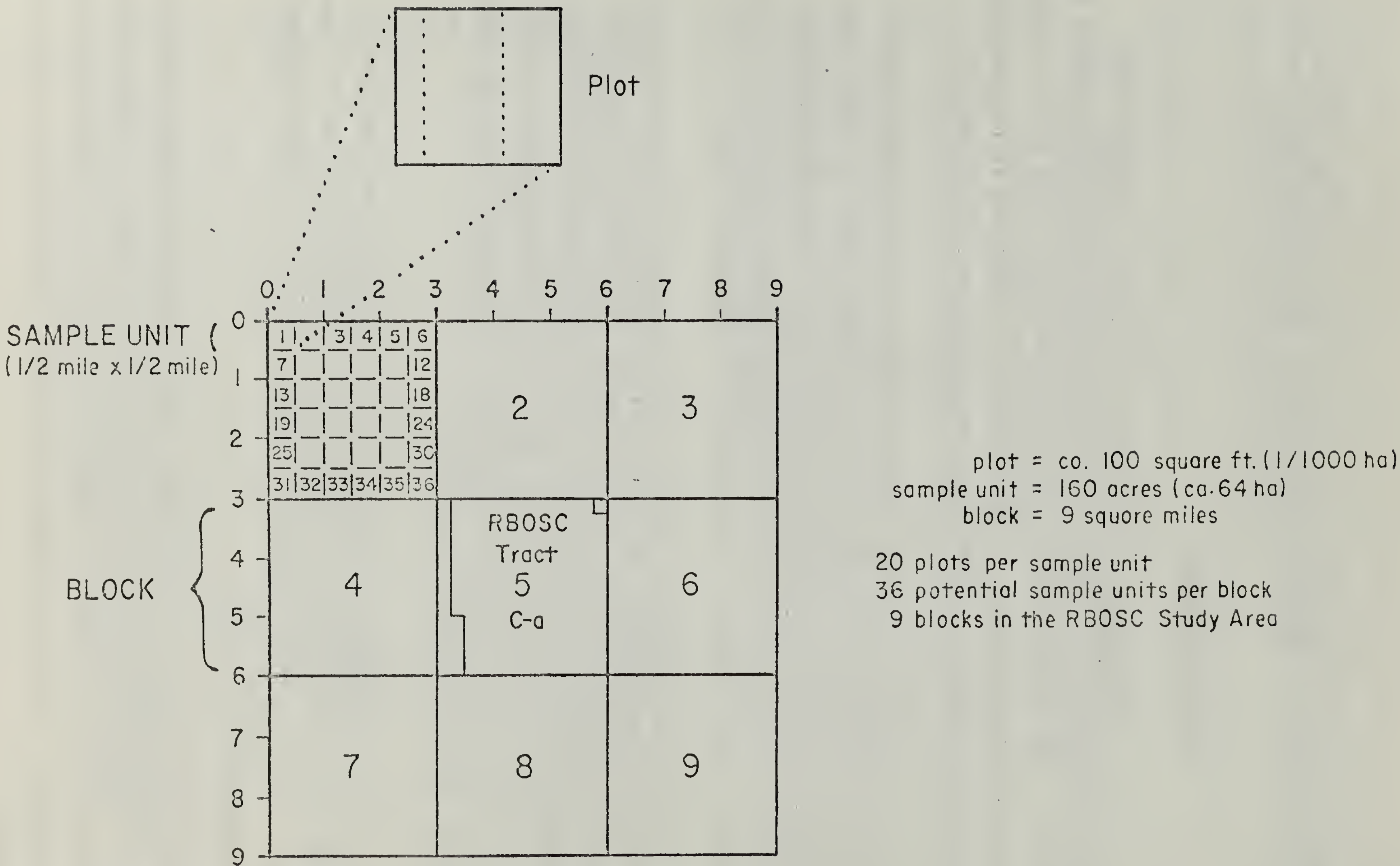



Figure 4.3. Study Area for Mule Deer Pellet-Group Counts. RBOSC Modular Development Phase Monitoring Program

Twenty plots or 2 transects of 10 plots each (ca. 100 sq ft (1/1000 ha) each) are randomly spaced within 63 randomly selected quarter section sampling units (7 units in each of the 9 blocks) (Figure 4.3). The boundary of each plot is determined by placing one end of a 5.8 foot (1.78 m) long chain on a center stake and walking around the stake with the opposite end of the chain pulled taut. Pellet-groups found within the circular plots are counted; to qualify as a group, six or more pellets must be present. Groups on the boundary of a plot are counted if one-half or more of the total number of pellets are within the plot. Sampling plots used during monitoring are marked with a numbered metal stake at the center of each plot.

Data are entered and stored on 9-track, 800 bpi magnetic tape and all data analyses are performed by computer. Documented data control procedures are followed.

c. Experimental design and data analysis - Tract C-a is in the center of a 9 x 9 mile (81 sq mi) study area which is divided into 9 blocks (3 x 3 miles or 9 sq mi each). Assessments of potential impacts of development require knowledge of deer distribution and abundance before mining or enhancement activities begin. To this end the following hypotheses will be tested.

$H_0$: Mule deer density estimates for RBOSC's 81 sq mi study area are not significantly different from those for Game Mangement Unit 22 (per unit area).

$H_0$: Mule deer numbers and distribution within the 81 sq mi study area are not significantly different before and during modular oil shale development activities.

A stratified random sampling program (Cochran 1963) was employed to estimate mule deer density from pellet group counts. For each 9 square mile block, 7 of the 36 quarter square-mile sample units were randomly selected then subsampled by two transects, one quarter mile apart, each containing 10 plots, 107.64 $ft^2$ (1/1000 hectare) in size, spaced at 0.05 mile intervals south to north. The principal reasons for stratification are outlined by Cochran (1963). In the following discussion, the notation employed in Cochran (1963) will be followed.

In order to determine confidence limits for the population mean density of pellet groups, an approximate method (Satterthwaite 1946) of assigning an effective number of degrees of freedom $n_e$ to v $(\bar{y}_{st})$ is:

$$n_e = \frac{(\Sigma g_h s_h^2)^2}{\Sigma \frac{g_h^2 s_h^4}{n_h - 1}}, \qquad \text{where } g_h = \frac{N_h(N_h - n_h)}{n_h}$$

Employing the above formulas the effective number of degrees of freedom is 31.

These confidence limits estimate the mean density of mule deer pellet groups within ±14% of the mean 90 percent of the time.

Mule deer density estimates are calculated from pellet-group data. The number of pellet groups per unit area, days of use by deer, and deer per acre in the study area are being determined as described by Overton (1971). These analyses provide an estimate of the number of deer per square mile in the 81 sq mi study area. This estimate will be compared with the CDOW estimate for Game Management Unit 22. If pellet-group data are available from CDOW, density estimates for Unit 22 and the 81 sq mi study area will be compared statistically (i.e., t-test) (Seber 1973).

If data collected from each block are adequate (sufficient number of pellet groups), differences in deer densities between blocks will be compared by the following ANOVA.

| | Source of Variation | Degrees of Freedom | F-Test |
|---|---|---|---|
| A. | Phase a = 2 | a-1 = 1 | A/H |
| B. | Seasons b = 2 | b-1 = 1 | B/H |
| C. | Location c = 9 | c-1 = 8 | C/H |
| D. | Phase x Seasons | (a-1)(b-1) = 1 | D/H |
| E. | Season x Location | (b-1)(c-1) = 8 | E/H |
| F. | Phase x Location | (a-1)(c-1) = 8 | F/H |
| G. | Phase x Season x Location | (a-1)(b-1)(c-1) = 8 | G/H |
| H. | Error (n = 7) | abc (n-1) = 216 | |
| | Total | abcn-1 = 251 | |

This three-way ANOVA is used to determine differences between phases (main effect A), between seasons (main effect B) and differences among locations (main effect C) which might indicate differences in deer distribution. First order interactions include phase and season (D), season and location (F) differences. The second order interaction determines deer density by phase, season and location. If significant differences occur, a multiple range test will be conducted to determine the sources of variation.

The feasibility of making statistical comparisons of pellet-group data from the nine blocks depends primarily on the number of plots sampled and the frequency and distribution of pellet groups counted. CDOW is currently conducting experimental pellet-group count studies for mule deer in the Piceance Creek basin. Results of pellet counts, and other CDOW mule deer studies, are being incorporated into RBOSC studies on a regular basis to the extent possible. CDOW studies may provide information useful in determining sample size (i.e., number of sample units and number of plots per sample unit) for the RBOSC studies.

4. <u>Mule Deer Road Kill Study</u> - The Piceance Creek Basin is the current center of a great deal of energy development activity including oil shale and natural gas. This increased activity has resulted in increased traffic flows across mule deer migration routes. The CDOW is interested in obtaining data relative to the mortality of mule deer as a result of deer-vehicle collisions.

a. <u>Objectives</u> - The objective of this program is to provide data on mule deer mortality along County Road 24 from Piceance Creek to Tract C-a for compilation and use by the CDOW.

b. <u>Method</u> - Mule deer mortality data will be collected three times per week, along a 13-mile stretch of County Road 24 from Piceance Creek to Tract C-a during prime migration periods (September - March). Data will be recorded on a field log by the RBOSC Field Biologist each sample day.

At the initial observance of a new carcass the location will be marked on a map (see map pocket) using a number representing the sequential kill count of the week (14 meaning the 14th new carcass sighted that week). Duplication of counts will be avoided by conspicuously marking the carcass with a patch of brightly colored spray paint or by marking the area with flagging. Marked carcasses will be omitted from subsequent counts. A new map will be used each week, and weekly kill counts as marked on the map plus supplementary data will be forwarded to the CDOW (through the Area Oil Shale Supervisor) on a monthly basis. Maps will be sequentially numbered for identification and dated. This information will be duplicated on the weekly field log.

Data to be recorded for each new carcass sighted will include:

- Date of observation
- Location (marked on map)
- Kill count number for the week (marked on map and field log).
- Time of day (a.m. or p.m.)
- Sex (male, female, undetermined)
- Age Group (Adult, Immature)
- Comments

These data will be recorded for each carcass only once, at the initial observation.

c. Experimental Design and Data Analysis - The program is designed to provide supplemental information to RBOSC for evaluation of effects of development on the mule deer herd and to assist the CDOW in compiling regional information on mule deer in the basin. The data will be reported in semi-annual reports, but no attempt will be made to quantify the data nor to test a stated null hypothesis.

5. Feral Horse Abundance

a. Objectives - Feral horses occur on and in the vicinity of Tract C-a. These horses are protected under federal law and are under the jurisdiction of the BLM. Feral horses compete with cattle and, to a lesser extent, with mule deer for available forage. The objective of feral horse monitoring studies is to provide qualitative information concerning the status of feral horses in the RBOSP study area.

b. Methods - Feral horses on Tract C-a and within three miles of the tract boundary (i.e., same study area as mule deer) are counted annually in January. Transects are flown with a helicopter, and the location and number of horses observed are recorded. The aerial census data will be supplemented by general observations (number; activity when observed e.g., watering, feeding) of horses recorded during other terrestrial ecology studies in May and September (Table 4.1).

c. Experimental design and data analyses - The total number of horses seen in the study area is compared with the number estimated to be in the area by state and federal agencies. This information provides a qualitative description of the status of feral horses in the study area.

Hypotheses - No statistical hypotheses are tested (only qualitative data are collected).

6. Threatened and Endangered Species and General Wildlife Survey

Baseline and interim monitoring studies indicate that Tract C-a does not provide critical habitat for any state of federally endangered species. Greater sandhill cranes were observed during the baseline studies on 84 Mesa, at the Stake Springs impoundment, and east of the 84 Ranch; a whooping crane was sighted east of 84 Ranch. Because RBOSC MDP activities are not expected to affect the areas where sightings have been made, a specific program for endangered species has not be included in the MDP monitoring program.

The RBOSC field biologist will be conducting studies on and near Tract C-a during all parts of the year. Observations of any threatened or endangered species will be reported to AOSO and appropriate studies will be initiated as determined by RBOSC and AOSO. A field log will be kept by the field biologist. Should unusual trends be noted or significant changes in animal behavior or population parameters be noted; the AOSO will be notified. RBOSC will work with the AOSO biologists to explain the reasons for such changes.

## LITERATURE CITED


Cochran, W.G. 1963. Sampling Techniques. 2nd Edn. John Wiley and Sons, New York. 413 pp.

Cole, G.P. 1963. Range Survey Guide. United States Dept. of the Interior, National Park Service, Washington, D.C.

Emlen, J.T. 1971. Population Densities of Birds Derived from Transect Counts. Auk 88:323-342.

Emlen, J.T. 1977. Estimating Breeding Season Bird Densities from Transect Counts. Auk 94:455-468.

Kirk, R.E. 1968. Experimental Design. Brooks-Cole Publishing Co., Belmont, Calif. 575 pp.

Overton, W.S. 1971. Estimating the Numbers of Animals in Wildlife Populations. Pages 403 - 456 in R. H. Giles, Jr. (Ed.) Wildlife Management Techniques. Edward Bros., Inc., Ann Arbor, Michigan. (For The Wildlife Society).

RBOSP. 1977. Final Environmental Baseline Report. Gulf-Standard, Denver, Co.

Satterthwaite, F.E. 1946. An Approximate Distribution of Estimates of Variance Components. Biometrics 2:110-114.

Seber, F.A.F. 1973. Estimation of Anival Abundance and Related Parameters. Griffin, London. 506 pp.

Snyder, D. P. 1978. Populations of Small Mammals Under Natural Conditions. Special Publ. Ser. 5. Pymatuning Lab. fo Ecol., Univ. of Pittsburgh.

Sokal, R. R., and F.G. Rohlf. 1969. Biometry. W.H. Freman and Co., San Francisco. 776 pp.

USDA, Forest Service. 1970. Range Environmental Analysis Handbook, 22109, 21RS. United States Department of Agriculture, Forest Service, Washington, D.C.

U.S. Salinity Lab Staff. 1944. Diagnosis and Improvement of Saline and Alkali Soils. USDA Handbook 60.

Wiens, J.A. 1977. On Competition and Variable Environments. Amer. Sci. 65:590.

# 5.0 AQUATIC STUDIES

The RBOSC MDP aquatic biological monitoring program was developed from an intensive analysis of baseline data and potential impacts of development. As part of the RBOSC Environmental Baseline Monitoring Program, data on aquatic biota were collected from surface waters of Tract C-a; Yellow Creek and the confluence of Yellow Creek and the White River from October 1974 through September 1976. Samples were collected from 35 sampling sites. The studies were designed to inventory the aquatic biota and to determine the baseline characteristics of aquatic resources. Aquatic biological studies were conducted in conjunction with extensive physicochemical studies of surface water and groundwater. Species composition, relative abundance and distribution of phytoplankton, zooplankton, macrophytes, periphyton, benthos, and fish were included. In addition, productivity studies were conducted for periphyton; and age, growth, conditions, and reproduction studies were conducted on fishes of the White River and Yellow Creek.

An analysis of the aquatic baseline data (FEBR 1977) indicated that phytoplankton, zooplankton, and macrophytes play relatively unimportant roles in the aquatic ecosystem of the area. Periphyton are the major primary producers, giving rise to a significant portion of the free-floating planktonic organisms. In the absence of fish, benthic organisms are the primary aquatic consumers on the tract. Fish occur only in Yellow Creek and the White River, because of the ephemeral nature of most on-tract surface water bodies. Distribution of macrophytes is limited to a few pond habitats.

Species composition, diversity and relative abundance for each of the biotic groups were compared for each year of baseline studies and among habitat types. Some fluctuations were noted but, for the most part, these parameters remained stable throughout the study period.

Periphyton communities in the pond habitats were more diverse than in the spring brook habitats, were similar to the creek habitats, and were less diverse than in the river habitats, as indicated by diversity indices. Mean organic weights were higher in the river habitats than in other areas.

High numbers of benthic taxa were found in the White River and Yellow Creek drainages. Substrate characteristics appeared to be of major importance in determining species diversities. The number of taxa was lower in the creek habitats than in other habitats. The heterogeneous substrate of the river habitats tend to increase benthic diversity. Physicochemical variations appear to influence benthic populations in the various habitat types. Many benthic organisms possess special food-gathering adaptations which allow them to survive in the somewhat adverse conditions of the area.

Only 15 species of fish were collected throughout the two-year baseline study. All specimens were taken from Yellow Creek and White River; no fishes were collected on the tract. Speckled dace was the most abundant species collected. No threatened or endangered species were found. In general, the distribution of fish catches was similar for both years. Most fish were taken from the White River rather than from Yellow Creek.

The overall objectives of the RBOSP Aquatic Baseline Studies were to characterize the existing aquatic communities on and in the vicinity of Tract C-a and to inventory aquatic habitats which may be affected by oil shale development.

In addition to the comprehensive analysis of baseline aquatic biological data, an intensive analysis of baseline hydrologic and water quality data was completed. Factor analysis, cluster analysis, and regression and correlation analyses were among the statistical techniques utilized to analyze the baseline hydrologic data.

Based upon the analysis of the aquatic and hydrologic baseline data, important or "indicator" parameters were selected for monitoring and evaluating the impacts of oil shale development on Tract C-a.

The next step in the development of the MDP aquatic monitoring program was to identify those aquatic factors likely to be impacted by development. This was done through the use of a "cause/effect" matrix, as discussed in the RBOSC Revised Detailed Development Plan (RBOSC 1977) and through the use of a "measurability" matrix (RBOSC 1977) which identified the measurability of a parameter, based upon experience with the analysis of RBOSC baseline data, expert judgment, and the current state-of-the-art in biometrics.

As a result of these analyses of aquatic baseline data, potential impacts of development, and of measurabiltiy, the aquatic monitoring program described in the following pages was developed.

## 5.1 ABIOTIC MONITORING

### A. Physical Measurements

1. Objectives - The objectives of taking physical measurements during the aquatic monitoring studies are to characterize the physical habitat conditions at each sampling site in order to relate these habitat data to the chemical and biological conditions observed at each site. These objectives are consistent with Section 1 (c) 1 of the Tract C-a lease.

2. Methods

a. Parameters - The physical parameters selected for these monitoring studies are those which are likely to be influenced by development (e.g., increased siltation and turbidity, changes in flows) and which have been shown through analysis of baseline data, to be of importance to the aquatic biota on and near Tract C-a. The parameters include: stream velocity, turbidity, dissolved oxygen, pH, alkalinity, specific conductance, water temperature, depth, width, and stream substrate. In addition to this limited physical data collection program, an extensive program for the collection and analysis of physical data, which will be used to document changes from baseline is described in Section 6.1, Surface Water Monitoring.

b. Monitoring locations - The sampling locations for the RBOSC aquatic MDP monitoring program are shown in Figure 5.1 and include:

- Station 13 (spring brook habitat) at the USGS gaging station in Corral Gulch (east)
- Station 14 (pond habitat) in Corral Gulch (east).
- Station 20 (spring brook habitat) at the USGS gaging station on Yellow Creek
- Station 21 (spring brook habitat) on Yellow Creek below the USGS gaging station
- Station 27 and 29 (back channel habitats) near the confluence of Yellow Creek with the White River. (Station 27 is considered an upstream "control" site and 29 a downstream "treatment" site.)

These stations correspond with sample site locations utilized during baseline studies to facilitate comparison between years.

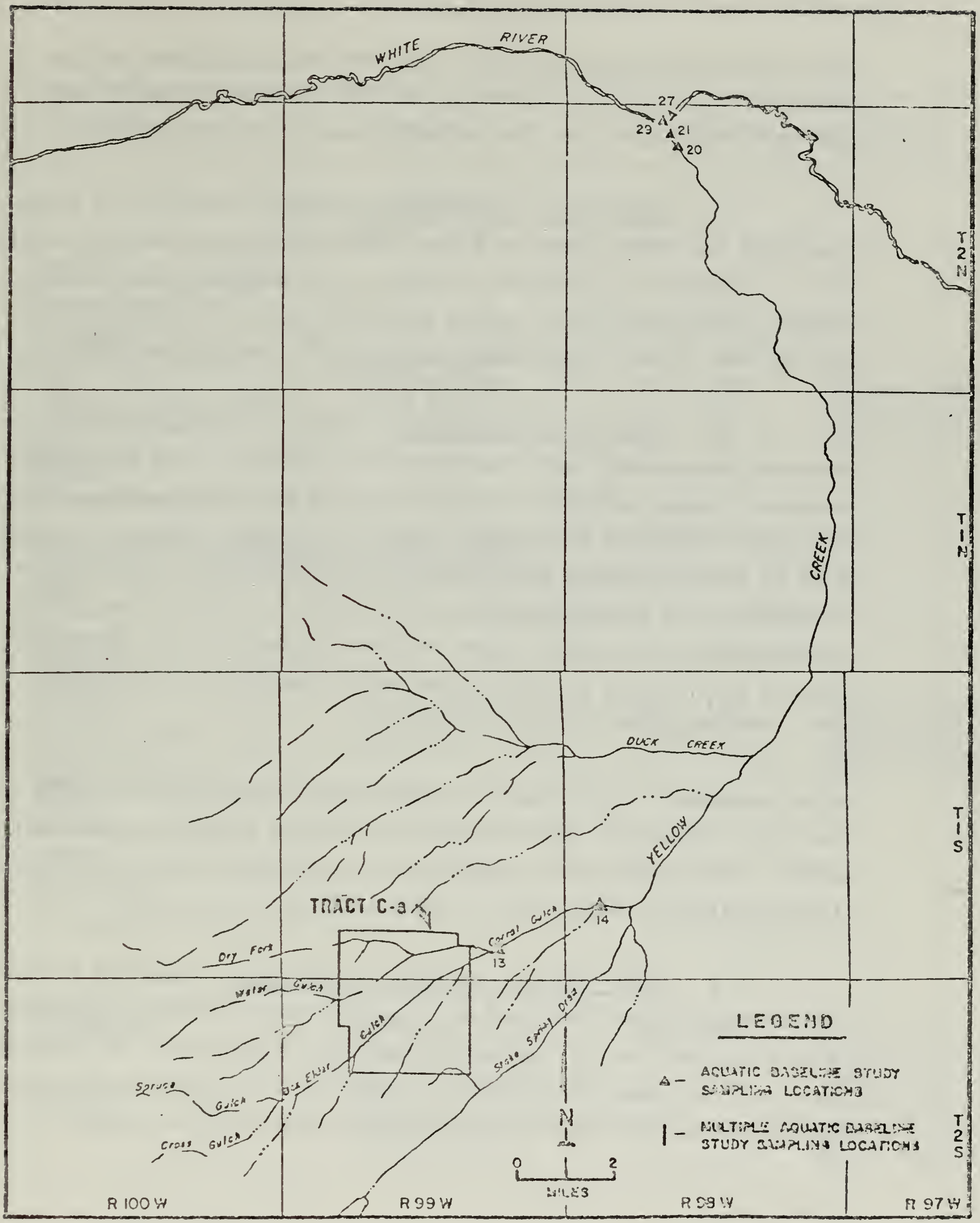



Figure 5.1. Locations of Aquatic Ecology MDP Sampling Sites

The sampling locations on Yellow Creek and the White River will be monitored to permit evaluations of the effectiveness of RBOSC water quality control plans and the potential impact of development.

c. Monitoring Frequency and Schedule - Sampling is being conducted six times a year to allow comparison of monitoring and baseline data. Sampling was conducted in October 1977 and April, June, July, August, and October 1978. During subsequent years, sampling will be carried out in April, May, June, July, August, and October (Table 5.1).

d. Data Collection Methods - Physical characteristics are measured concurrently with the collection of chemical and biological samples. Stream velocity is measured with a Gurley flowmeter or equivalent. The stream substrate is visually classified at each station at the same time as benthic samples are collected. The turbidity of each sample is determined with a Hach Photometric Turbidimeter or equivalent. Field measurements of dissolved oxygen are made according to the Alsterberg (Azide) modification of the Winkler Method (American Public Health Administration, APHA 1976).

Other parameters (and methods of measurement) which are determined in the field include pH (portable meter), specific conductance (portable meter), water temperature (thermistor or equivalent) depth, width, and total alkalinity (colorimetric; APHA, 1976).

e. Data Handling and Quality Assurance - Data are entered and stored on nine track, 800 bpi, magnetic tape. Quality assurance controls as defined by the Quality Assurance Program will be implemented. Work will be conducted according to specific work instructions which conform to accepted methods for collection and handling of data.

Table 5.1. MDP Aquatic Ecology Studies Monitoring Program Schedule

| Parameter | Location | Start Date | Frequency |
|---|---|---|---|
| | **Abiotic** | | |
| Physical Measurements | | | |
| Stream Velocity<br>Turbidity<br>Dissolved Oxygen<br>pH<br>Specific Conductance<br>Water Temperature<br>Depth<br>Width<br>Stream Substrate | Stations 13,14<br>20,21,27,29<br>(See Figure 6) | Oct. 1977 | 6 times/year<br>(April, May, June<br>July, Aug.,Oct.) |
| Water Quality Measurements (White River) | | | |
| Boron<br>Calcium<br>Chloride<br>Fluoride<br>Magnesium<br>Nitrate<br>Orthophosphate<br>Potassium<br>Total Phosphate<br>Silica<br>Sulfate<br>Sodium<br>Alkalinity<br>Total dissolved solids<br>Bicarbonate | Stations 27,29<br>(See Figure 6) | Oct. 1977 | 6 times/year<br>(April, May, June<br>July, Aug., Oct.) |
| | **Biotic** | | |
| Periphyton | Stations 13, 14<br>20, 21, 27, 29<br>(See Figure 6) | Oct. 1977 | 6 times/year<br>(April, May, June<br>July,Aug., Oct.) |
| Benthos | Stations 13, 14<br>20, 21, 27, 29<br>(See Figure 6) | | 6 times/year<br>(April, May, June<br>July, Aug., Oct.) |

f. Experimental Design - Physical data collected as part of the aquatic studies will be utilized in characterizing the aquatic habitat and will be related to the chemical and biological data collected at the same time. Comparison of changes in physical conditions over time will be made using the extensive physical data collected as a part of the hydrology monitoring program.

B. Water Quality Measurements

1. Objectives - The objectives of including water quality studies in the aquatic studies program will be to monitor those chemical characteristics which the analysis of RBOSC baseline data (FEBR 1977) have shown to contribute most to the natural variability in White River water quality, to monitor year to year differences in White River water quality, and to monitor natural and development-related variation in White River water quality. These objectives are consistent with Section 1(c)1 of the Tract C-a lease.

2. Methods - Chemical parameters for water quality studies were chosen after an exhaustive analysis of baseline water quality data. Methods of statistical analysis included: factor analysis, cluster analysis, regression analysis, and correlation analysis as discussed in the RBOSC Final Enviornmental Baseline Report (1977). The analyses were based upon data from many sampling locations, and frequent sample collections.

From the analysis of baseline White River water quality data, it appears that the analysis of 14 parameters at two sampling locations in the White River will provide sufficient indication of change in order to meet the stated objectives. Observations of unexpected changes in water quality will be carefully evaluated and will trigger additional sampling, if warranted.

a. Parameters - Parameters included in the White River water quality monitoring program are: boron, calcium, chloride, fluoride, magnesium, nitrate, orthophosphate, potassium, total phosphate, silica, sulfate, sodium, total alkalinity, total dissolved solids, and bicarbonate.

b. Monitoring Locations - Two sampling sites (Figure 5.1) are included in the White River water quality monitoring program:

- Station 27 (above the confluence with Yellow Creek)
- Station 29 (below the confluence with Yellow Creek)

Station 27 serves as a control, Station 29 as a treatment location in the design of these studies.

c. Monitoring Frequency and Schedule - Sampling is conducted six times a year to allow comparison between monitoring and baseline data. Sampling is scheduled for October 1977; for April, June, July, August, and October 1978; and April, May, June, July, August and October during subsequent years.

d. Sample Collection and Analysis - Table 5.2 lists the analytical methods, limits of detection, and methods of sample preservation for the water quality parameters. Replicate samples (2) are collected at each location.

e. Data Handling - Data are entered and stored on nine track, 800 bpi, magnetic tape according to procedures outlined in the Quality Assurance Program.

3. Experimental Design and Data Analysis Techniques - In fulfilling the objectives of these studies, the following hypotheses will be tested.

Table 5.2. RBOSC White River Water Quality Analyses

| Parameter | Detection Limits | Methodology | Sample Preservation |
|---|---|---|---|
| Alkalinity (total) | 2.0 mg/l | Colorimetric | Refrigeration |
| Boron | 0.2 mg/l | APHA[1] 405A | None Required |
| Calcium | 0.02 mg/l | Atomic Absorption | HCl* |
| Chloride | 0.4 mg/l | Potentiometric | None Required |
| Fluoride | 0.02 mg/l | Electrode | None Required |
| Magnesium | 0.005 mg/l | Atomic Absorption | HCl |
| Nitrate | 0.01 mg/l | APHA[1] 419C | $HgCl_2$ |
| Orthophosphate | 0.01 mg/l | EPA[2] | $HgCl_2$ |
| Potassium | 0.01 mg/l | Atomic Absorption | HCl |
| Total Phosphate | 0.01 mg/l | EPA[2] | $HgCl_2$ |
| Silica | 0.04 mg/l | APHA[1] | HCl |
| Sulfate | 1.0 mg/l | APHA[1] 427C | Refrigeration |
| Sodium | 0.01 mg/l | Atomic Absorption | None Required |
| Total Dissolved Solids | 1 | Filtration & Evaporation | None Required |

[1] American Public Health Association (APHA)

[2] Environmental Protection Agency (EPA)

* HCl is an optional preservative

Note: Samples will be retained for three months following submission of the year-end report.

$H_0$: There is no significant difference in the water quality charateristics of the White River between the baseline and development monitoring periods at the same location.

$H_0$: There is no significant difference in the water quality characteristics between sample sites.

For the experimental design, Station 27 will serve as a control site and Station 29 will serve as a treatment site. Baseline data will also be defined as a control, with MDP data serving as the treatment.

Since there were six data collection periods per year during the baseline and six during MDP monitoring, Spearman Rank correlations can be utilized for each station (Baseline/MDP monitoring) and between stations for the baseline period and for the monitoring period (after six total years of data collection) to test the aforementioned hypotheses.

Based upon analysis of baseline data, it is expected that data will be within $\pm$25 percent of the mean (concentration) 95 percent of the time.

## 5.2 BIOTIC MONITORING

As indicated in the introduction to the Aquatic Studies program, selection of biological parameters for inclusion in the RBOSC MDP monitoring program was based upon a comprehensive analysis of the aquatic baseline data and upon an exhaustive analysis of potential impacts to the aquatic systems and of the measurability of the aquatic parameters.

### A. Periphyton

1. Objectives - The objectives of the periphyton studies are to monitor the biomass, species composition, relative abundance, and diversity of the periphyton communities in the study area in order to

identify and document changes, if any, in these characteristics which occur as tract development proceeds, in support of the overall objectives of the environmental program.

The periphyton data from these studies must be related to the physical, chemical, and benthos data to provide an overall assessment of the changes in the aquatic habitats on and near Tract C-a. The objectives of these studies are consistent with Section 1(c)1 of the Tract C-a lease.

2. Methods

a. Parameters - The periphyton characteristics selected for monitoring include species composition relative abundance, biomass, and species diversity. These parameters correspond to parameters studied during baseline and will provide data suitable for comparison with baseline values.

b. Monitoring Locations - The same monitoring locations identified in Section 5.1. A.2 are utilized for RBOSC periphyton studies. Station 27 and baseline data will serve as "controls". Station 29 and MDP data will serve as "treatments".

c. Monitoring Frequency and Schedule - Sampling frequency will be six times a year to allow comparison of monitoring and baseline data. Sampling was conducted in October 1977 and April, June, July, August, and October 1978. During subsequent years sampling is scheduled (Table 5.1) in April, May, June, July, August, and October.

d. Sample Collection and Analysis - Calculations of the sample size required to obtain an accuracy of $\pm$25 percent of the mean (total relative abundance) 95 percent of the time for each type of habitat were used in defining the periphyton sampling program. At

Stations 13 (springbrook habitat), 14 (pond), and 27 and 29 (White River), six replicate samples are collected; four of these are used to determine relative abundance and the remaining two are used to determine biomass. At Stations 20 and at 21 (Yellow Creek) ten replicate samples are collected; eight of these are used to determine relative abundance and the remaining two are used to determine biomass.

Samples of periphyton are collected from areas of equivalent flow, if possible. Rocks that have relatively flat upper surfaces and are positioned at mid-depth in riffles are selected for the collection of periphyton samples. The rocks are carefully removed from the streams and each replicate is taken by removing the periphyton from a 50 $cm^2$ area with a toothbrush and water (Northern States Power Co., 1974). The resultant suspension of material is preserved in 5 percent neutralized formalin.

In the laboratory, the preserved periphyton samples are diluted to a constant volume, an aliquot is removed, centrifuged, and washed with distilled water. The samples are then stained and dehydrated in the centrifuge, using successive spinnings and decantings. A number of drops of the final xylene-periphyton suspension is placed on a microscope slide with Hyrax, heated gently, and covered with an ultra-thin coverglass. The final mounts are retained in the permanent voucher collection. See Aquatic Annual Report for methods (RBOSP 1976).

Periphyton is studied using a microscope and counting all organisms appearing in one randomly chosen transect at 1000X (oil immersion). The whole slide is then surveyed at 100X to identify and enumerate larger rare species. Counts are expressed as cells per unit area; these data are used to compute relative abundance and species diversity. Slides are retained in a voucher collection.

Biomass determinations are made by weighing the samples dried at a constant temperature of 105 C followed by ashing at 550 C and reweighing (Vollenweider 1969). The calculated ash-free dry weights are estimates of the organic weight or biomass of the periphyton.

e. Data Handling - Data are entered and stored on nine track, 800 bpi, magnetic tape according to documented quality assurance procedures.

3. Experimental Design and Data Analysis - In fulfilling the objectives of these studies, the following hypotheses will be tested:

$H_0$: There is no significant difference in the relative abundance of periphyton between the baseline and development monitoring periods at the same locations.

$H_0$: There is no significant difference in periphyton diversity between baseline and development monitoring periods in similar habitats.

$H_0$: There is no significant difference in the biomass of periphyton between the baseline and development monitoring periods in similar habitats.

These hypotheses for biomass are tested by using analysis of variance techniques (Table 5.3). For relative abundance, the hypotheses presented above will be evaluated by utilizing a Spearman Rank Correlation. For diversity, a t-test will be utilized in evaluating the above hypotheses.

"One of the most important items of information that can be obtained from species identification is the recognition of small changes or trends or shifts from sensitive to tolerant species" (Patrick 1977). Following this philosophy, the largest part of our judgement of community

Table 5.3 Analysis of Variance for Biomass of Periphyton

| Source | d-f | F Test |
|---|---|---|
| A. Phase a = 1 | a-1 = 1 | $\frac{A}{H}$ |
| B. Date: Phase b = 11 + 5 | $(b-1)_1 = 11$<br>$(b-1)_2 = 5$ | $\frac{B}{H}$ |
| C. Station C = 6 | C-1 = 5 | $\frac{C}{H}$ |
| D. Date: Phase: Station | $(b-1)_1(b-1)_2(a-1)$<br>$(c-1) = 80$ | $\frac{D}{H}$ |
| E. Error | (abc) (n-1) = 216 | |
| Total | nabc - 1 = 323 | |

change will be based on species data. This will be done by comparing pre-development and development phase populations of species which have known ecological spectra. Changes in populations of key species may not indicate significant habitat change if those species replacing declining ones have similar tolerance. These changes may be detected in spite of diversity or other frequently used indices remaining the same. The non-statistical test of changes in species composition may be presented as a non-statistical hypothesis as follows:

> There is no major change in periphyton species composition between baseline and development monitoring periods at the same locations.

In addition to the above, analyses of pre- and post-construction communities will be made using an index of similarity which will provide a quantification (percent) of the degree of difference (or similarity) among communities of comparable sampling periods. These computations will be made using densities of each species (Owen 1973).

Diversity indices will be used as a final means of comparison of pre- and post-construction phase periphyton communities. Information theory diversity indices (Shannon-Wiener, Lloyd et al. 1968, EPA 1973) as well as Evenness and Richness (Pielou 1969, Margalef 1969) will be computed. While these indices do not take into account species composition, they do provide useful measures of community structure.

In summary, the pre- and post-construction periphyton communities will be compared using several measurements of community structure and density. No single index or means of comparison will provide a total picture of changes that may occur, since several indices may change, while others will not. Statistical analyses will be employed to detect changes in relative abundance and diversity among sites and between baseline and MDP monitoring phases. In the final analysis, the use of the above methods will be tempered with biological judgement to decide the significance of the analytical results. In the event that significant changes are detected, additional studies will be triggered as necessary to investigate the cause of the changes. These studies may include increased sampling frequencies, addition of various parameters, or additional statistical analysis, relating to interacting parameters.

B. Benthos

1. Objectives - The objectives of the benthic (macroinvertebrate) studies are to monitor relative abundance, species composition, and diversity of the benthic communities to identify and document changes, if any, in these characteristics which occur as tract development proceeds.

The benthos data from these studies must be related to the physical, chemical, and periphyton data to provide an overall assessment of the changes in the aquatic habitats on and near Tract C-a. The objectives of these studies are consistent with Section 1(C)1 of the Tract C-a lease.

2. Methods

a. Parameters - The benthos characteristics selected for monitoring include: species composition, relative abundance, and species diversity.

b. Monitoring Locations - The same monitoring locations identified in Section 5.1.A.2 are utilized for RBOSC benthic studies. Station 27 will serve as the location control; baseline data will serve as the temporal control. Station 29 will serve as a treatment site, as will MDP data.

c. Monitoring Frequency and Schedule - Sampling frequency, at least initially, will be six times a year to allow comparison of monitoring and baseline data. Sampling was conducted in October 1977 and April, June, July, August, and October 1978 and is scheduled during subsequent years (Table 5.1) for April, May, June, July, August, and October.

d. Sample Collection and Analysis - As discussed in Section 3, Experimental Design and Data Analysis, baseline benthos data were utilized to calculate the sample size required for statistical accuracy for each type of habitat. These calculations indicated that only semi-quantitative benthic sampling can be accomplished within the limits of time and habitat available near Tract C-a. The following sampling program was developed with that philosophy.

At each sampling site, replicate samples (3) are collected with a modified Hess sampler. During RBOSP aquatic baseline studies, this sampler which yields quantitative results was proven effective in rubble and gravel substrates.

The modified Hess sampler has been previously described in RBOSC work-scopes as a modified Surber sampler. In reality, the modified Hess sampler used throughout the two years of aquatic baseline studies, during interim monitoring studies, and during the proposed development monitoring studies, is a modification of the original Surber square-foot sampler similar to that described by Waters and Knapp (1961). The modified Hess sampler (FD8-522 $cm^2$) is a lightweight, shallow-water benthos sampler. It is cylindrical or elliptical in shape and consists of a metal frame with #30 mesh (0.6 mm aperature) side curtains. The side screening prevents the capture of drifting organisms.

After collection, benthos samples are washed in buckets that have bottoms fitted with a U.S. Standard No. 30 sieve, and preserved with neutralized 10 percent formalin.

Standardized methods of sample processing and analysis are utilized in the laboratory. Samples are first rinsed in 20 cm, No. 60 sieves with light-pressure fine spray to remove specimens from rocks and any fine sediments. The samples are then hand-sorted under dissecting microscopes at 6X magnification. Organisms are removed from the sample with forceps, eye droppers and probes to petri dishes or watch-glasses containing water. Samples are systematically searched, and the examined portions are pushed aside. Unidentified material is also removed along with the organisms and examined under dissecting microscopes. The organisms are stored in plastic capsules in 70 percent ethanol.

With few exceptions, benthic organisms are identifiable to genus without special preparation. Organisms are identified to the lowest taxon possible. Individuals are usually identified under the dissecting microscope or with temporary slides (under water) under a compound microscope.

Chironomidae and Oligocheata are cleared in xylene and then mounted on permanent slides in Canada balsam. Only complete oligochaetes with intact anterior portions are enumerated.

Only those individuals which are living at the time of collection, as indicated by presence of fleshy tissue, are enumerated for the purpose of estimating populations. Empty mollusc shells, exuvia, reproductive structures, etc. are retained as aids in identification and compilation of qualitative species lists, but are not used for estimates of population densities. A special reference or voucher collection is maintained apart from other specimens.

As part of the analysis of the aquatic baseline data, a calculation of adequate sample size was made for macroinvertebrates in each habitat type. The calculation indicated that prohibitive numbers of replicate samples would be required to achieve a high degree of statistical accuracy. Collection of such large numbers of samples would require a prohibitive amount of time and effort and such extensive destructive biological sampling would likely have a greater inpact on the benthic communities than development of the tract itself.

For these reasons the benthic studies have been designed to provide semi-quantitative data, which when related to the physical, chemical, and periphyton studies, will provide an overall assessment of the changes in the aquatic habitats on and near Tract C-a. Should major changes be detected in the benthos populations under study, additional studies may be initiated to determine the source of the change. These studies could involve additional physical and chemical chacterization studies or more intensive biotic sampling. The need and approach to increased efforts will be worked out with the AOSO.

e. Data Handling - Data are entered and stored on nine track, 800 bpi, magnetic tape according to documented quality assurance procedures.

3. Experimental Design - In fulfilling the objectives of these studies, the following hypotheses are being tested:

$H_0$: There is no significant difference in the relative abundance of benthic macroinvertebrates between the baseline and development monitoring periods at similar locations.

$H_0$: There is no significant difference in the species diversity of benthos between the baseline and development monitoring periods at similar locations.

$H_0$: There is no significant difference in species diversity of benthos between Stations 27 and 29.

$H_0$: There is no significant difference in the relative abundance of benthos between Stations 27 and 29.

For relative abundance, the above hypotheses will be tested utilizing an index of similarity and Spearman Rank Correlation analyses. The hypotheses for diversity will be tested by utilizing a t-test. An index of similarity will also be used in assessing trends in the benthic species composition.

## LITERATURE CITED


American Public Health Association (APHA). 1976. Standard Methods for Examination of Water and Waste Water. 14th Ed APHA, New York. 874 pp.

Environmental Protection Agency. 1973. Biological field and laboratory methods for measuring the quality of surface waters and effluents. Ed. C.I. Weber. EPA- 670/4 - 73-001. July 1973.

Environmental Protection Agency. 1975. Monitoring Reference and Equivalent Methods. Code Fed. Reg. 40(30). February 18, 1975.

ESG Quality Assurance Manual. 1976. Issue B. NUS Corporation. Rockville, Maryland.

Lloyd, M., J.H. Zar, and J.R. Karr. 1968. On the calculation of information - theoretical measures of diversity. The American Midland Naturalist. 79(2): 257-272.

Margalef, R. 1969. Perspectives in ecological theory. University of Chicago Press. 111 pp.

Northern States Power. 1974. Environmental Report. AEC Docket Nos. STN-552, 50 - 484, 50 - 487.

Owen, B.B., Jr., 1973. The Effects of Increased Temperatures on Periphyton Communities of Artificial Stream Channels. Ph.D. dissertation. U. of Alberta, Canada.

Patrick, R., 1977. Ecology of Freshwater Diatoms - Diatom Communities. In D. Werner (Ed.). The Biology of Diatoms. Blackwell Scientific Publications, London.

Pielow, E.C. 1969. An introduction to mathematical Ecology. John Wiley and Sons. p. 333.

RBOSP. 1976 Annual Aquatic Baseline Report. Gulf-Standard. Denver, Co.

RBOSP. 1977. Final Environmental Baseline Report. Gulf-Standard, Denver, Co.

RBOSP. 1977. Revised Detailed Development Plan Tract C-a. Gulf-Standard, Denver, CO.

Waters, T.F. and K.J. Knapp. 1961. An Improved Stream Bottom Fauna Sampler. Trans. Amer. Fish. Soc. 90(2): 225-226.

Vollenweider, R.A. 1969. A Manual on Methods for Measuring Primary Production in Aquatic Environments. International Biological Program Oxford, England. 213. p.

## 6.0 HYDROLOGY STUDIES

This hydrology monitoring program is based on the data collected during the two-year baseline program and the interim studies data. The baseline data collection program, consisting of surface water and groundwater hydrology, was conducted to define stream flow (both quality and quantity), locations of springs and seeps, amount and distribution of rainfall, and aquifer characteristics. These data were examined using statistical methods including frequency analysis, scattergram analysis, bivariant correlation, factor analysis, discriminant function, and trend analysis.

### A. Springs and Seeps

Most of the springs are fed by alluvial or upper bedrock aquifers. Of the thirty-seven springs and seeps which were identified, several of these springs were periodically monitored for velocity and quality. Six stations (1, 2, 3, 4, 5, and 8) were reported in the FEBR because they were the only ones from which the water came exclusively from the spring source. The water sources of the springs at the monitoring stations were suggested as follows: The springs at Stations 1 and 2 have as their water source the alluvial aquifer, whereas Stations 3, 4, 5, and 8 derive their spring water from the upper oil shale aquifer. As suggested by the AOSO Spring 14 was added to and Station 4 dropped from the monitoring program. The data collected to date does not indicate that Spring 14 derives its water from an exclusive source.

Generally, water quality of springs and seeps approximates the quality in the alluvial and upper aquifer. There is conclusive evidence that the lower aquifer does not directly contribute water to any of the springs and seeps that were monitored.

Discrete and diffuse groundwater discharge from springs and seeps affects the quality of surface water. Water quality samples were taken with the same frequency and at the same locations as physical data to maintain continuity. The baseline aquatic resources program included six monitoring sites on streams below spring and seepage areas. Baseline water quality values are given in Table 2.9, page II-37 of the Final Environmental Baseline Report. Total dissolved solids, a generalized indicator of water quality, was shown in the baseline program to be the following:

TOTAL DISSOLVED SOLIDS:

| | Maximum (mg/l) | Minimum (mg/l) |
|---|---|---|
| Station 1 | 607.00 | 484.00 |
| Station 2 | 768.00 | 558.00 |
| Station 3 | 974.00 | 476.00 |
| Station 5 | 1080.00 | 936.00 |
| Station 8 | 740.00 | 543.00 |
| Station 14 | 1350.00 | 1163.00 |

Specific conductivity will be used in the monitoring program to effectively and quickly denote water quality changes.

B. Streams

Water flows were continually monitored during the baseline program with a network of seven stream gaging stations.

At these stations, temperatures and specific conductance were continuously monitored and recorded and automatic sediment samplers were operated. Precipitation data were supplied by three recording and three storage gages on and around Tract C-a. These data indicate that the average precipitation on Tract C-a is about 10 to 13 inches per year with the maximum amounts falling in the spring and summer seasons. As indicated by the three recording-type precipitation gages, the greatest amount of precipitation falls along Cathedral Bluffs and the lowest amount falls at the confluence of Yellow Creek and the White River.

Three of the seven surface water gaging stations were found to flow during most of the period of record. These three stations are Corral Gulch near the west line of Tract C-a, Corral Gulch east of Tract C-a, and Yellow Creek near the White River, Colorado. The remaining four stations were found to have flows only during spring snowmelt runoff. In general, the streams were found to be intermittent with a few reaches having perennial flows due to groundwater discharge.

Intense summer precipitation events are an important source of surface water runoff. Water quality, as indicated by specific conductance, generally declines from the headwaters downstream. Highest average specific conductance values occur during the winter before snowmelt begins. Water temperatures follow seasonal trends while suspended sediment loads are generally related to flow and the rate at which the flow changes.

The Stake Springs Draw Station was dropped from the MDP Monitoring Program because of the remoteness of the drainage to the area of impact.

Summary tables were prepared for all baseline parameters for each station and best-fit estimates of geometric means and geometric deviations, number of samples on which they were based, confidence limits, and points on the probability density curve are presented in RBOSP Progress Report 10. Tables 2.10 through 2.15 of the FEBR show summary statistics for USGS monitoring stations with corresponding aquatic resources program data for comparison. Table 2.16 in the FEBR presents summaries of White River surface water quality. Chi squared goodness-of-fit statistics were derived and over half of the derived curves were acceptable using this criterion at the 5 percent confidence level. Failure to meet this criterion was related to resistant right-skewness evident even after log transformation. The best-fit log-normal distribution was retained as a best estimate for the tables, even though some of the heavy metals could have fit one of the external type distributions. Analysis error in the determination of trace heavy metal concentrations could also modify the distribution. No data on the standard deviation of lab determination of heavy metal concentrations were available.

## C. Alluvial Aquifers

Alluvial, perched, and deep bedrock aquifers are present in the Piceance Creek basin. The only major aquifers found in the vicinity of Tract C-a were the alluvial and deep bedrock aquifers.

Alluvium occurrences were mapped from aerial photographs in the vicinity of Tract C-a. In order to determine the depth, thickness, and water saturation of the alluvium, an alluvial test drilling program was initiated in April 1975. Those holes which contain water are now being used as monitor holes.

A total of seven alluvial aquifer monitor holes, was completed, all drilled to bedrock. Of these seven, no water was encountered in three and they have remained dry throughout the monitoring period. The remaining four have had measurable water levels since the initial construction.

Three additional monitoring holes were drilled and are being monitored during the MDP program.

Table 2.79 in the FEBR provides a summary of data of the alluvial monitor holes on Tract C-a and along Corral Gulch which contained alluvial water. Water levels, pH, temperature, and conductivity were measured in the field each month.

The majority of the alluvial monitor holes which contained water showed increasing water level from the months of March through June during baseline. The magnitude of the increases varied depending upon the drainage system in which the hole was located. During the remaining summer, fall, and winter months, water levels generally declined as shown in Figure 2.48 of the FEBR. Water levels will be recorded daily during the MDP.

The results of the alluvial monitoring program indicate that the major drainage systems have water saturated alluvium and that in many of the minor drainage systems the alluvium is dry. In the major drainage systems the data indicate a seasonal trend in the water levels. This trend shows rising water levels during the snowmelt runoff period and declining water levels the remainder of the year. The limited observations to date from the continuous water level records indicate that the alluvial aquifers respond only indirectly to regional and local precipitation events.

D. Deep Bedrock Aquifers

Two deep bedrock aquifers--the upper oil shale aquifer and the lower oil shale aquifer are found on Tract C-a.

The upper oil shale aquifer is in the vicinity of the Mahogany Zone while the lower oil shale aquifer is associated with the R 3 Zone. Both of the deep oil shale aquifers average approximately 200 feet in thickness and are artesian.

All three of the aquifer systems, the alluvial aquifer and two deep aquifers, are considered tributary, i.e., waters pumped from these aquifers will affect the direction or rate of surface water flow within a period of 40 years. In general, both conductivity and temperature increased with the depth of the aquifer during baseline. Water movement, which has a preferred direction from northwest to southeast, may be limited in the upper aquifer by fault structures. In view of the limited movement of the groundwater, semi-annual measurements of water quality parameters will be collected to detect perturbations to the system.

Deep aquifer hydrologic information was collected during core hole drilling, formal pumping tests, and the baseline data collection program. The deep aquifer hydrological program included measurement of water levels. Water levels in the aquifers were dynamic throughout the baseline period. Aquifer static water levels (SWL) were approaching equilibrium since the aquifers were isolated after a period of connection through open holes. Water levels in both aquifers appear to fluctuate seasonally. This fluctuation is more pronounced in the upper aquifer than in the lower aquifer.

Table 6.1 provides a summary of the Hydrology Monitoring Program. The data collected during the MDP Monitoring Program are to be compared to the baseline values using the same statistical methods as those used to analyze the baseline data (See Figure 6.1 for ranges in water quality of groundwater types). The baseline data are programmed and stored in such a manner as to allow input and statistical analysis of new data acquired during the MDP program. If anomalies are indicated, the source of the anomaly will be analyzed through

TABLE 6.1 Summary Hydrology Program

| | Continuously | Annually | Semi-Annually | Quarterly |
|---|---|---|---|---|
| **SURFACE WATER** | | | | |
| Springs and Seeps: | | | | |
| Flow | | | | X(6) |
| Conductivity | | | | X(6) |
| Temperature | | | | X(6) |
| pH | | | | X(6) |
| DOC | | | | X(6) |
| Water Quality | | X(6) | | |
| Stream Gaging Stations: | | | | |
| Flow | X(6) | | | |
| Conductivity | X(6) | | | |
| Temperature | X(6) | | | |
| Suspended Sediment | X(3) | | | |
| Limited Water Quality | | | | X(6) |
| Baseline Water Quality | | | X(6) | |
| **GROUNDWATER** | | | | |
| Alluvial Holes: | | | | |
| Water Levels | X(4) | | | X(5) |
| Limited Water Quality | | | | X(9) |
| Baseline Water Quality | | | X(9) | |
| Deep Oil Shale Aquifer Holes: | | | | |
| Aquifer Water Level | X(7) | | | |
| Baseline Water Quality | | X(7) | | |

( ) Indicates the number of sampling sites.

NOTE: For a complete list of parameters and sampling locations, please refer to TABLES 6.2 through 6.5. This table is only a summary.

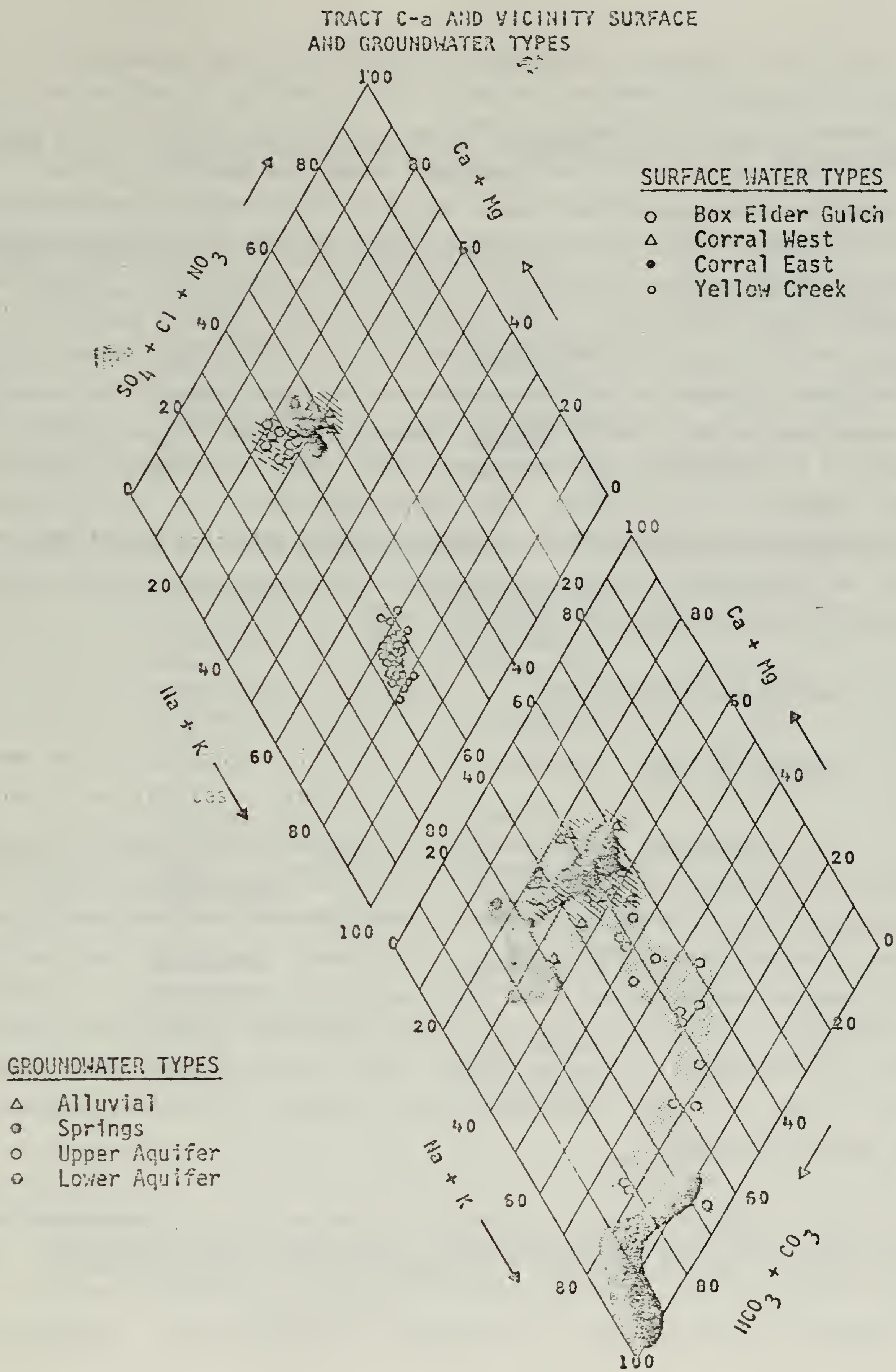



Figure 6.1. RANGES IN WATER QUALITY TYPES, TRACT C-a AREA

the statistical methods dicussed above. Analysis of such anomalies will be used to determine both changes from the baseline hydrology as well as possible development-related environmental effects. If these statistical analyses indicate that variations in water quality exceed expected fluctuations from the baseline norm, then measures will be taken to determine if contamination from development operations has occurred. Samples will be collected and analyzed to determine type of contaminant and to trace the source. Significant changes in water quality may trigger additional aquatic studies monitoring, if changes are of a magnitude what could affect aquatic biota. If contamination is indicated, appropriate mitigation measures will be taken. Environmental hydrologic monitoring is being done as frequently as necessary to identify the impacts of the mining and operation activities. Other hydrologic studies are being conducted in conjuction with engineering activities, and intensive environmental monitoring is being conducted during MDP pump tests (Section 6.4). As development progresses, the monitoring program will be adjusted as necessary in consultation with the AOSS.

## 6.1 SURFACE WATER MONITORING

### A. Springs and Seeps

1. Objectives - The purpose of monitoring and observing major springs and seeps during the MDP is to collect and analyze current conditions and compare these to conditions existing prior to mining and development operations. The objective of this process is to detect changes in the character of springs and seeps; determine if the changes are significant; and analyze the changes to determine if they are caused by mining or development operations. In addition, it is the objective of this monitoring program to determine if lease and permit requirements are being met, as well as applicable laws and regulations.

2. Methods - Flow, conductivity, temperature, dissolved organic carbon (DOC), and pH will be measured quarterly (See Table 6.2). DOC fractionation was also conducted once, to determine the baseline norm and will be conducted in the future, as necessary as defined below. Conductivity

Table 6.2. Monitoring Schedule and Methodology for MDP Monitoring of Springs and Seeps, Tract C-a.

Monitoring Stations - Springs 1,2,3,5,8,and 14

Monitoring Frequency - Quarterly (January, April, July and October)

| Parameters | Methodology |
|---|---|
| Flow | Weir (F) |
| Conductivity | Meter (F) |
| Temperature | Thermometer (F) |
| pH | Paper (F) |
| DOC** | Analyzer (L) |

Monitoring Frequency - Annually (July) (All laboratory analyses)

| Parameters* | Methodology |
|---|---|
| Alkalinity | Titrimetric |
| Ammonia | Titrimetric |
| Bicarbonate | |
| Calcium | Titrimetric |
| Carbonate | |
| Chloride | Titrimetric |
| Color | |
| Fluoride | Electrode |
| Hardness | |
| Iron | Phenanthroline |
| Magnesium | Titrimetric |
| Nitrate plus Nitrite | Cadmium Reduction |
| Odor | |
| Phosphate | Colorimetric |
| Potassium | AA |
| Suspended Sediment | |
| Silica | Colorimetric |
| Sodium | AA |
| Sulfate | Turbidimetric |

(F) Field
(L) Laboratory
* Parameters, except Odor, Color, and Suspended Sediment, are dissolved
** DOC fractionations will be conducted as necessary (See p. 106).

3. <u>Experimental Design and Data Analysis</u> - The summary of the baseline chemical analysis is reported on Table 2-9 of the FEBR II-37. The majority of the items was sampled from 18 to 24 times during the baseline period. Statistical analyses completed on these data included high, low, geometric mean, and geometric deviation for each of the 23 constituents. Conductivities were measured six times a year and reported in the quarterly reports.

Because of different data requirements during the baseline period, total flow measurements were not taken at that time. Water velocity measurements were taken using a pigmy flow meter. Because the prime area of interest at the current time is to detect any change in flow, weirs are now being used to measure the water quantity. Stations 1 and 2 will be used as control stations. They are located at a remote distance upstream of the tract and were found during the baseline analysis (page II-11 of the FEBR), to have as their source, the alluvium as the aquifer of origin. Stations 3, 5, 8, and 14 were found to have as their source, the upper aquifer. Therefore, these four stations will be defined as the treatment stations, subject to potential impact by tract operations. They will be compared to flows at the control sites (1 and 2).

The total flow from these springs cannot be quantified from the baseline data. However, presence or absence of flow can be used in a qualitative manner for comparative purposes. The purpose of the MDP measurements is to quantify flow on a quarterly basis and to determine if the dewatering and mining activities are appreciably affecting surface flows. Once quantitative data are available, appropriate null hypothesis will be developed for testing the assumption that flows won't be affected adversely by tract activities.

DOC measurements are being conducted at this time to expand the baseline. This analysis will be critical at a time after the burns have been conducted and retorts abandoned. Should degradation to the upper aquifer occur, it can be detected by changes in pH, conductivity, and DOC.

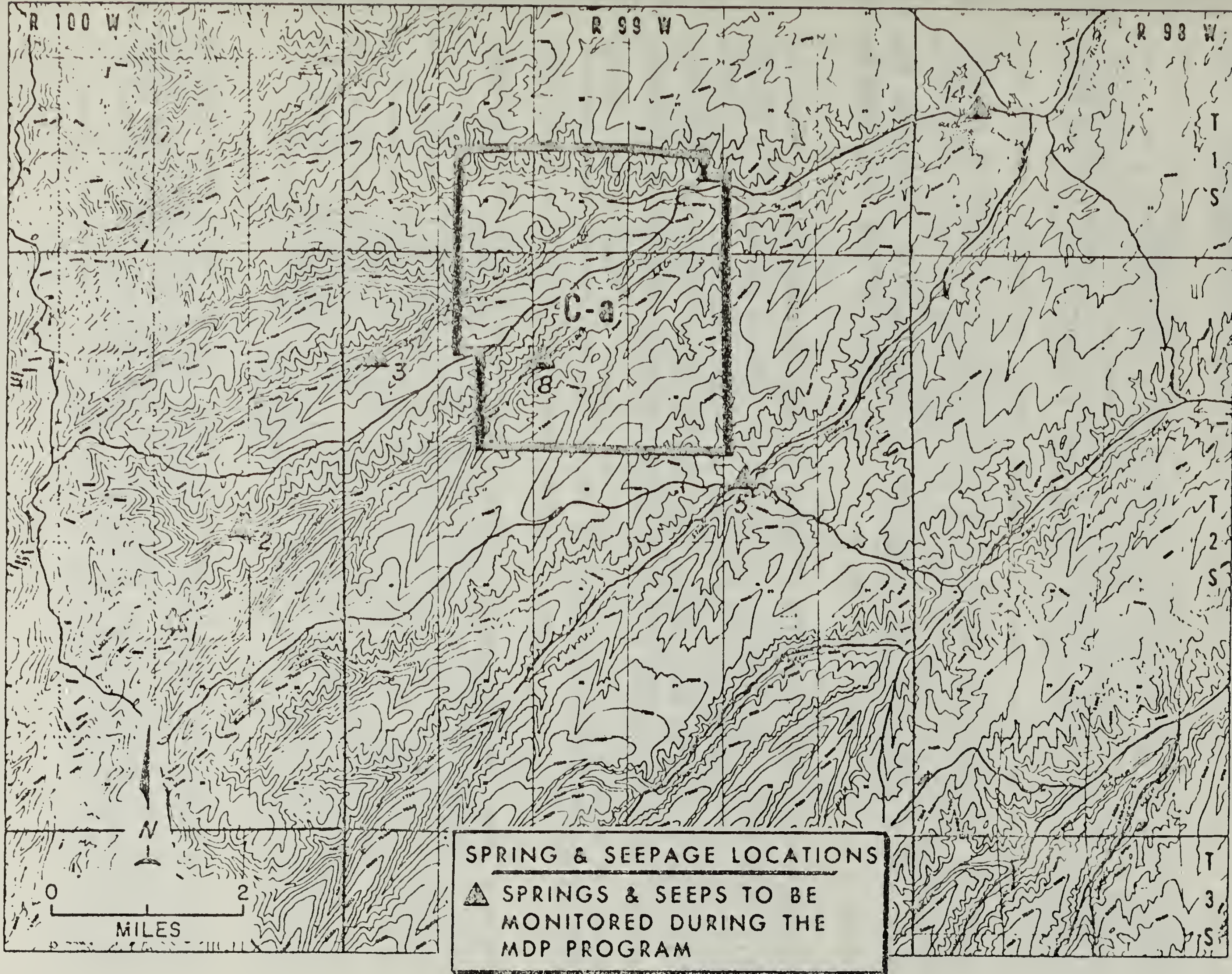



Figure 6.2. Springs and Seeps to be Monitored During the MDP

3. Experimental Design and Data Analysis - The summary of the baseline chemical analysis is reported on Table 2-9 of the FEBR II-37. The majority of the items was sampled from 18 to 24 times during the baseline period. Statistical analyses completed on these data included high, low, geometric mean, and geometric deviation for each of the 23 constituents. Conductivities were measured six times a year and reported in the quarterly reports.

Because of different data requirements during the baseline period, total flow measurements were not taken at that time. Water velocity measurements were taken using a pigmy flow meter. Because the prime area of interest at the current time is to detect any change in flow, weirs are now being used to measure the water quantity. Stations 1 and 2 will be used as control stations. They are located at a remote distance upstream of the tract and were found during the baseline analysis (page II-11 of the FEBR), to have as their source, the alluvium as the aquifer of origin. Stations 3, 5, 8, and 14 were found to have as their source, the upper aquifer. Therefore, these four stations will be defined as the treatment stations, subject to potential impact by tract operations. They will be compared to flows at the control sites (1 and 2).

The total flow from these springs cannot be quantified from the baseline data. However, presence or absence of flow can be used in a qualitative manner for comparative purposes. The purpose of the MDP measurements is to quantify flow on a quarterly basis and to determine if the dewatering and mining activities are appreciably affecting surface flows. Once quantitative data are available, appropriate null hypothesis will be developed for testing the assumption that flows won't be affected adversely by tract activities.

DOC measurements are being conducted at this time to expand the baseline. This analysis will be critical at a time after the burns have been conducted and retorts abandoned. Should degradation to the upper aquifer occur, it can be detected by changes in pH, conductivity, and DOC.

## B. USGS Gaging Stations

1. Objectives - The purpose of monitoring at USGS stream gaging stations during the MDP is to identify current conditions and compare these to conditions existing prior to mining and development operations. The objective of this program will be met by determining changes in quantity or quality of the streams; determining if the changes are significant, and analyzing these changes to determine if they are caused by mining or construction of associated facilities. In addition, it is the objective of this monitoring program to determine if lease and permit requirements are being met, as well as applicable laws and regulations.

2. Methods - Selected physical and chemical parameters are measured at intervals as shown in Table 6.3 to provide a comprehensive development monitoring data base on surface water. Data are collected either once initially, continuously, quarterly, or semi-annually. DOC fractionation was conducted initially and will be collected thereafter as necessary, as defined below.

Surface water quantity and quality are monitored through the use of six water gaging stations (Figure 6.3) identified as follows:

A. (09306237) Dry Fork near west line Tract C-a (Control)
B. (09306235) Corral Gulch near west line Tract C-a (Control)
C. (09306240) Box Elder Gulch near west line Tract C-a (Control)
D. (09306242) Corral Gulch east of Tract C-a (Treatment)
E. (09206255) Yellow Creek near White River, Colorado (Treatment)
F. (09206241) "Rinky Dink" Gulch near east line Tract C-a (Control)

Stations on the western side of Tract C-a (upstream) are defined as control sites not likely to be affected by development. Stations on the eastern side of the tract are treatment sites since they may potentially be affected. The frequency, parameters, and methodology of measurement are set forth in Table 6.3.

TABLE 6.3 Monitoring Frequencies and Methodology for Collection of Surface Water Gaging Station Data, Tract C-a.

---

Monitoring Stations - USGS Stream Gages A,B,C,D,E and F

Monitoring Frequency - Continuously

| Parameters | Methodology |
|---|---|
| Flow | Recorder (F) |
| Conductivity | Recorder (F) |
| Temperature | Recorder (F) |
| Suspended Sediment** | Automatic Sampler (F)<br>Analysis (L) |

Monitoring Frequency - Quarterly[1]

| Parameters* | Methodology |
|---|---|
| Alkalinity | (USGS Conducting) |
| Bicarbonate | |
| Boron | |
| Calcium | |
| Chloride | |
| DOC*** | |
| Fluoride | |
| Magnesium | |
| Nitrate + Nitrite | |
| Potassium | |
| pH | |
| Silica | |
| Sodium | |
| Sulfate | |

Monitoring Frequency - Semi-Annually (April, October)

| Parameters* | Methodology |
|---|---|
| Alkalinity | (USGS Conducting) |
| Aluminum | |
| Ammonia | |
| Arsenic | |
| Barium | |

Semi-Annual Parameters, Cont'd

Beryllium
Bicarbonate
Biological Oxygen Demand
Bismuth
Boron
Bromide
Cadmium
Calcium
Carbonate
Chemical Oxygen Demand
Chloride
Chromium
Color
Coliform,
  Total
  Fecal
Conductivity, Specific
Copper
Cyanide
Discharge
Fluoride
Gallium
Germanium
Hardness
Iron
Kjeldahl Nitrogen
Lead
Lithium
Magnesium
Manganese
Mercury
Molybdenum
Nickel
Nitrate + Nitrite
Odor
Oil & Grease
Organic Carbon, dissolved ***
Oxygen, dissolved
Pesticides
  Diazinon
  Endrin
  Lindane
  Malathion
  Methyl Parathion
  Parathion

TABLE 6.3 USGS Steam Gages, Continued

---

Semi-Annual Parameters, Cont'd

- PC Napthalenes
- Silvex
- Toxaphene
- 2,4-D
- 2,4,5-T
- pH
- Phenols
- Phosphaste,
  - Dissolved
  - Ortho
- Potassium
- Radioactivity
  - Gross Alpha
  - If > 4 pci/l
  - Than $Sr^{90}$
  - $Ce^{137}$
  - Gross Beta
  - If > 100 pci/l
  - Then $Sr^{90}$
  - $Ce^{137}$
- Residue, Total Filtr.
- Residue, Total NonFi.
- Sediment Discharge
- Sediment Susp.
- Selenium
- Silica
- Silver
- Sodium
- Strontium
- Sulfate
- Sulfide
- Temperature
- Tin
- Titanium
- Total Dissolved Solids
- Turbidity
- Vanadium
- Zinc
- Zirconium

---

NOTE: The USGS is conducting the analysis used for the above parameters according to accepted EPA and Standard methods.

(F) Field

(L) Lab

* Parameters except pH, BOD, COD, color, coliform, conductivity, discharge, odor, oil and grease, residue-total filtered, sediment discharge, sediment suspended, temperature, and turbidity are dissolved.

** Stations B, D and $D_1$ only

*** DOC fractionations will be conducted as necessary (See p. 114).

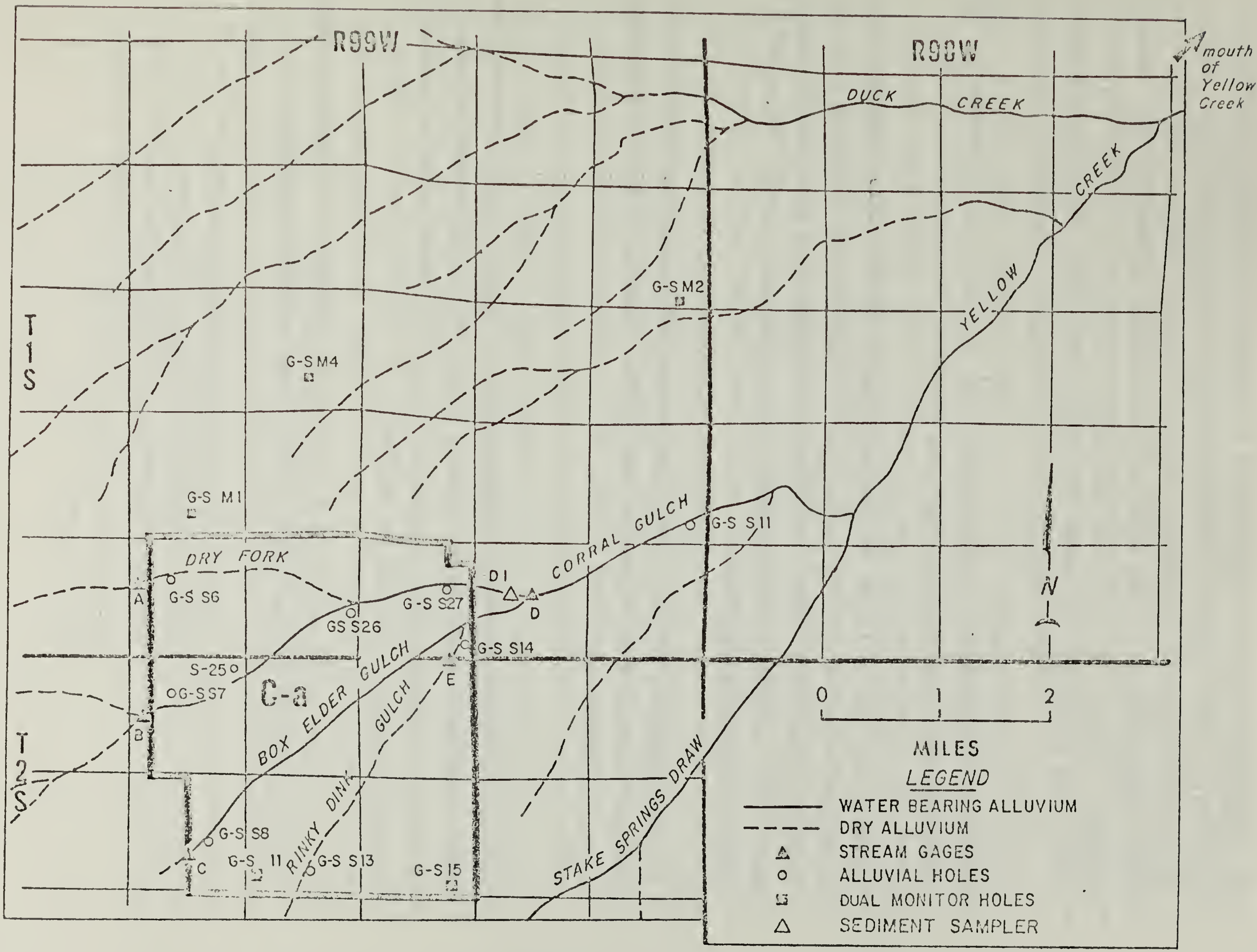



Figure 6.3. Locations of Monitoring Stations for Hydrology Studies During the MDP

If conductivity (which is continuously recorded) at the Corral Gulch Station east of Tract C-a, (USGS No. 09306242) exceeds the one percent value for the cummulative frequency distribution for the seasonal baseline data for over three days continuously, the water will be sampled and analyzed for sodium, chloride, silicon, pH, DOC, and the major ions discussed above. This will allow us to determine from which of the aquifer sources, if any, the anomaly has resulted. If it is determined that the anomaly was due to some other activity, then the complete set of semi-annual analysis (Table 6.3) will be conducted. Detection of exceedences will be assured by daily monitoring and comparison with baseline curve by RBOSC personnel.

Sediment data are collected at surface gages B and D. A new sediment data collection point $D_1$ will be constructed upstream of the confluence with Box Elder Gulch on Corral Gulch. These data are collected using automatic equipment. This equipment is programmed to collect data at various intervals depending upon the stream flow.

DOC fractionations will be carried out to determine contamination by organics whenever DOC data exceed baseline means by four times or if significant trends in DOC are identified.

As potential by-products, gases, and other possible inputs to the hydrologic system are identified, these parameters may be added to the monitoring program. Additional knowledge of possible inputs will be gained during the early portion of the MDP and the monitoring program will be adjusted as conditions warrant in consultation with the AOSS.

3. Experimental Design and Data Analysis - The surface water hydrology studies are designed to evaluate the following hypothesis:

> $H_0$: There is no significant difference in the chemical composition of the surface water at control and treatment sites on the same drainage (e.g. between A and D; between B and D, between C and D).

Evaluation of these hypotheses will begin with a general comparison of water type. Trilinear diagrams will be plotted using the percentages of equivalents per million of major ions (Ca + Mg, Na + K, $HCO_3$ + $CO_3$, $SO_4$ + Cl + $NO_3$). During baseline analysis, each of the station's data formed a fairly dense cluster. If the development reporting period values fall outside the baseline clusters, additional statistical analyses will be performed for the parameters exhibiting fluctuations to test the null hypothesis

A quantitative comparison of water quality will be conducted by statistically examining each potentially affected parameter. Probabilistic determination of expected water quality will be based on data collected during the baseline monitoring program. These expectations assume that the proportions of stream flow components present during baseline are representative of long-term variations. This may be a reasonable assumption as runoff quantities in the baseline period range from somewhat above normal to below normal. Baseline analysis determined that the best description of the probability density function was calculated using the method of non-linear least squares with a log normal transformation. Estimates encompassing 99% of the expected population will be developed for each parameter from geometric mean and deviation. Data from the development reporting period will be compared with these estimates. If the data are within the expected ranges, the null hypothesis will be accepted.

To evaluate sources of dissolved chemical constituents and mechanisms of dissolution, correlation matrices will be constructed for all chemical parameters at each station. Because the structure of each matrix is very complex, factor analysis will be performed to attempt to simplify this information. This multivariate statistical technique is used to redistribute the explained variance present in the matrix into a set of factors that are linear combinations of the original variables. Factor scores will also be calculated, plotted on graphs, and compared to surface water hydrology to aid in interpretation. For these tests, parameters analyzed during baseline will also be analyzed during the MDP for each station or set of stations. If the major parameters are loaded onto similar factors and the same type of correlations occur, the null hypothesis will be accepted.

If the null hypothesis is rejected at any stage in its evaluation, an anomaly is indicated. The source of the anomaly will be analyzed through the statistical methods discussed above. This analysis will determine changes in both baseline hydrology and possible hydrologic environmental effects. If contamination from development operations is indicated, appropriate mitagation measures will be taken.

Another hypothesis to be tested is:

> $H_0$: There is no significant difference in the physical parameters of the surface water measured at each station during the baseline and development period.

Evaluation of this hypothesis will begin with an examination of continuous conductivity, flow, and temperature data at each station. Probabilistic determinations of expected ranges for each parameter will be based on data collected during the baseline monitoring program. The best description of the probability density function for flow and temperature was calculated using the arithmetic mean and standard deviation assuming a normal distribution. Conductivity must undergo a log normal transformation before the probability density function can be calculated. With this parameter, the method of nonlinear lease squares is used with the geometric mean and deviation. For each parameter, estimates encompassing 99% of the expected population will be developed from baseline data. The development reporting period values will be compared with these estimates. Duration curves for each parameter will also be plotted. If the development values are within the expected ranges, the null hypothesis will be accepted.

Sediment Station B will be used as the control station while Stations D and $D_1$ will be used as the treatment stations. After a relationship between sediment data from Station D and Station $D_1$ has been established, sediment Station D will be dropped if approved by the AOSS.

To determine the interrelationships of the continuously recorded parameters, correlation and regression analyses will be conducted. Each station will be considered separately. Log values of all parameters except pH will be used in plotting scattergrams. Results from the development values will be compared with the baseline results. If both sets of data have similar significant correlations, the null hypothesis will be accepted.

If the null hypothesis is rejected at any stage in its evaluation, an anomaly is indicated. The source of the anomaly will be analyzed through the statistical methods discussed above. This analysis will determine both changes in baseline hydrology as well as possible hydrologic environmental effects. If impact from development operations is indicated, appropriate mitigation measures will be taken and additional monitoring will be triggered in consultation with the AOSS.

## 6.2 GROUNDWATER MONITORING

### A. Alluvial Aquifers

1. Objectives - The purpose of monitoring and observing the alluvial aquifers during the MDP is to analyze current conditions and compare those to conditions existing prior to mining and development operations. The objective of this process is to detect changes in the character of the alluvium; determine if the changes are significant; and analyze the changes to determine if they are caused by mining or development operations, such as accidental oil spills, breakthrough of the injection water into the lower aquifer, or releases of dewatering water into the alluvial aquifers. In addition, it is the objective of this monitoring program to determine if lease and permit requirements are being met, as well as applicable laws and regulations.

2. Methods - The locations of the alluvial groundwater monitoring holes are shown in Figure 6.3. Selected physical and chemical parameters are measured at various frequencies, as indicated in Table 6.4, to provide a comprehensive alluvial aquifer data base. The parameters measured may be limited

TABLE 6.4 Monitoring Schedule and Methodology for the MDP Alluvial Aquifer Monitoring Program Tract C-a

---

Monitoring Stations - Alluvial Aquifer Holes - G-S S7, G-S S11, G-S S26 and G-S S27

Monitoring Frequency - Continuously

| Parameter | Methodology |
|---|---|
| Water Levels | Recorders (F) |

---

Monitoring Stations - Alluvial Aquifer Holes G-S S6, G-S S8, G-S S13, G-S S14, G-S S25

Monitoring Frequency - Quarterly (January, April, July, October)

| Parameter | Methodology |
|---|---|
| Water Level | Tape or "M" Scope (F) |

---

Monitoring Stations - G-S S6, G-S S7, G-S S8, G-S S11, G-S S13, G-S S14, G-S S25, G-S S26, G-S S27

Monitoring Frequency - Quarterly (January, April, July, October)

| Parameters* | Methodology |
|---|---|
| Alkalinity | Titrimetric |
| Bicarbonate | Titrimetric |
| Calcium | Titrimetric |
| Chloride | Titrimetric |
| DOC | Carbonaceous Analyzer |
| Fluoride | Electrode |
| Magnesium | Titrimetric |
| Nitrate + Nitrite | Cadmium Reduction |
| Potassium | AA |
| pH | Paper (F), Meter (L) |
| Silica | Colormetric |
| Sodium | AA |
| Sulfate | Turbidimetric |

---

Monitoring Stations - G-S S6, G-S S7, G-S S8, G-S S11, G-S S13, G-S S14, G-S S25, G-S S26, G-S S27

Monitoring Frequency - Semi-Annual (April, October)

| Parameters* | Methodology |
|---|---|
| Alkalinity | Titrimetric |
| Aluminum | AA |
| Ammonia | Titrimetric |

(Semi-Annual Parameters)

| Parameters* | Methodology |
|---|---|
| Arsenic | Gutseit |
| Barium | Spectrographic |
| Beryllium | Spectrographic |
| Bicarbonate | Titrimetric |
| Bismuth | Spectrographic |
| Bromide | Titrimetric |
| Boron | Colorimetric |
| Cadmium | AA |
| Calcium | Titrimetric |
| Carbonate | Titrimetric |
| Chemical Oxygen Demand | Titrimatric |
| Chloride | Titrimetric |
| Chromium | AA |
| Color | |
| Conductance | Meter (F) |
| Copper | Spectrographic |
| Cyanide | Colorimetric |
| Dissolved Organic Carbon (DOC Fractionation) | Carbonaceous Analyzer (Non Standard Method) |
| Dissolved Solids, Total | Dried at 180°C |
| Fluoride | Electrode |
| Gallium | Spectrographic |
| Germanium | Spectrographic |
| Iron | Phenanthroline |
| Lead | AA |
| Lithium | Spectrograhpic |
| Magnesium | Titrimetric |
| Manganese | Spectrographic |
| Mercury | AA |
| Molybdenum | Spectrographic |
| Nickel | AA |
| Nitrate + Nitrite | Cadmium Reduction |
| Odor | |
| pH | Paper (F) |
| Phenols | 4-AAP |
| Phosphate, Dissolved | Colorimetric |
| Potassium | AA |
| Radioactivity | |
| Gross Alpha | |
| If > 4 pci/l | Proportional Counter |
| Then $Ra^{226}$ | Alpha Particle Spectrometric |
| Natural Uranium | Fluorimetric |
| Gross Beta | |
| If > 100 pci/l | Proportional Counter |
| Then $Sr^{90}$ | Proportional Counter |
| $Ce^{137}$ | Gamaspectronmetry |

Semi-Annual Parameters

| Parameters* | Methodology |
|---|---|
| Selenium | Fluorimetric |
| Silica | Colorimetric |
| Sodium | AA |
| Strontium | AA |
| Sulfate | Turbidimetric |
| Sulfide | Titrimetric |
| Temperature | Thermometer (F) |
| Titanium | Spectrographic |
| Vanadium | Spectrographic |
| Zinc | AA |
| Zirconium | Spectrographic |

* Unless the methodology is noted otherwise, the methodology to be used is laboratory. Parameters except COD, color, conductivity, odor, pH, and temperature are dissolved.

by the quantity of water present at the station. Additional analyses may be performed if warranted by changing conditions.

During the baseline period, a total of seven shallow alluvial monitor holes was drilled and monitored. The monitoring of six holes plus three new alluvial holes (Figure 6.3) will meet the objectives of the MDP environmental hydrology monitoring program.

The major ions and sodium will be measured and used for a cation-anion balance as a quality control check on the lab work.

If increased concentrations of DOC or oil and grease are detected over a period of time, then analyses of these substances will be conducted to determine the possible source. These analyses can determine the type of material, i.e., No. 2 diesel fuel, unleaded gasoline, raw shale oil, etc. Once the specific oil and grease product is known, the source will be determined and corrected. The effect of the leak or spill will be mitigated.

Two of the new alluvial holes, G-S S25 and G-S S26, are located downstream from the proposed mine shaft retention pond and will provide data on leakage from sediment collection ponds. The third new alluvial hole, G-S S27, is located on Corral Gulch downstream from all surface disturbances (Figure 6.3). These new holes are completed according to methods outlined by the AOSS. A DOC fractionation will be performed for these holes if at any time there is water present and repeated if DOC values exceed the baseline means by four times or if significant trends in DOC are identified.

As other possible inputs to a hydrologic system are known, these may be added to the monitoring program. Additional knowledge of possible inputs will be gained during the early portion of the MDP.

Sample collection and laboratory analysis procedures will follow those identified in the RBOSC Quality Assurance Manual.

3. Experimental and Data Analysis - The hydrology studies are designed to evaluate the following hypothesis.

$H_0$: There is no significant difference in chemical composition of the alluvial water measured between the baseline (control) and development (treatment) periods.

Preliminary evaluation of this hypothesis will begin with a general comparison of water types between the baseline and development reporting period. Tri-linear diagrams will be plotted using the percentages of equivalents per million of the major ions (Ca + Mg, Na + K, $HCO_3$ + $SO_4$ + Cl). During the baseline period, the alluvial aquifer values formed a fairly dense cluster. If the values for the development period fall within this cluster, the null hypothesis will be initially accepted. If they fall outside this cluster; then those parameters which deviate from the expected range will be analyzed statistically to test the hypothesis.

Each individual chemical parameter will be examined. Probabilistic determination will be based on data collected during the baseline monitoring program to provide a detailed comparison of water composition. Baseline analysis determined that the best description of the probablity density function was calculated using the method of nonlinear lease squares and assuming a log-normal distribution for all chemical parameters. Estimates encompassing 99% of the expected population for each parameter will be calculated using the baseline geometric mean and deviation. Data collected during the development phase will then be compared with these estimates. If the values are within the expected ranges, the null hypothesis will be accepted.

The next aspect of evaluating the null hypothesis will be a check of the source aquifer for the development period. During the baseline program, discriminant function analysis was used to statistically determine the most efficient chemical parameters for differentiating between water quality in the three aquifers. This statistical technique transforms a standardized set of measurements on a sample into a linear function of original variables. Once this function has been developed for samples from a known source, it can be used to identify probable sources for unknown samples. The null hypothesis will be accepted if the alluvial aquifer is classified as the source aquifer.

To evaluate sources of dissolved chemical constituents and mechanisms of dissolution, a correlation matrix will be constructed for all chemical parameters. Because the structure of this matrix is very complex, factor analysis will be performed to attempt to simplify this information. This multivariate statistical technique is used to redistribute the explained variance present in the matrix into a set of factors that are linear combinations of the original variables. Two factor analyses were computed during the baseline period, one using 27 parameters and the other using a smaller subset of the first (11 parameters). The development period data will be studied by factor analysis with the same parameters as in the baseline period. The null hypothesis will be accepted if the major parameters are correlated when loaded onto similar factors.

If the null hypothesis is rejected at any stage in its evaluation, an anomaly is indicated. The source of the anomaly will be analyzed through the statistical methods discussed above. This analysis will allow us to determine changes in both baseline hydrology and possible hydrologic environmental effects. If contamination from development operations is indicated, appropriate mitigation measures will be taken.

Another hypothesis which will be evaluated is as follows:

> $H_0$: There is no significant difference in the physical parameters of the alluvial water measured between baseline (control) and development (treatment) periods.

Evaluation of this hypothesis will begin with an examination of conductivity, pH, temperature, and water level for each alluvial hole. Analysis of baseline indicated that the best description of the probability density function for conductivity could be calculated by using the method of moments and assuming a log-normal distribution. Temperature, pH, and water levels were found to be normally distributed. Estimates encompassing 99% of the expected population for each parameter at each hole will be developed from baseline data. Data collected during the development phase will then be compared with these estimates. If the values are within the stated deviations, the null hypothesis will be accepted.

To investigate sources and relative amounts of recharge, histograms of water levels versus streamflow and hydrographs will be plotted for alluvial holes. Hydrograph data will be fitted to exponential curves to determine alluvial groundwater recession patterns. The results from the development monitoring data will then be compared to the baseline analysis. If similar conclusions are formed from both values, the null hypothesis will be accepted.

Water level and conductivity data will be compared over all stations to examine associations during periods of seasonal trends. Correlation matrices will be calculated using linear regression analysis. The development matrices will then be compared with baseline matrices. The null hypothesis will be accepted if the development data correlations are similar to correlations which were demonstrated during baseline.

If the null hypothesis is rejected at any stage in its evaluation, an anomaly is indicated. This source of the anomaly will be analyzed through the statistical methods discussed above. This analysis will determine changes in both baseline hydrology and possible hydrologic envirnomental effects. If impact from development operations is indicated, appropriate mitigation measures will be taken.

B. Deep Oil (Upper and Lower) Shale Aquifers

1. Objectives - The purpose of monitoring and observing deep (upper and lower) oil shale aquifers during the MDP is to collect and analyze current water levels and water quality and compare those to water levels and water quality existing prior to mining and development operations. The objective of this process is to detect changes in the character of the aquifer; determine if the changes are significant; and analyze the changes to determine if they are caused by mining or development operations, such as dewatering and reinjection. In addition, it is the objective of this monitoring program to

determine if lease and permit requirements are being met, as well as applicable laws and regulations.

2. Methods - The location of the monitoring holes are shown on Figure 6.3. Water levels will be monitored continuously. Water quality measurements will be taken on a semi-annual basis. Baseline data indicate that annual measurements will be sufficient to provide information on any regional effects of mining and operational activities because of the slow movement of groundwater. The parameters and methodology are shown on Table 6.5.

Dewatering rates will be determined during engineering studies.

Sample collection and laboratory analysis procedures will be conducted in accordance with those specified in the RBOSC Quality Assurance Manual.

3. Experimental Design and Data Analysis - The hydrology studies are designed to evaluate the following hypothesis.

> $H_0$: There is no significant difference in chemical composition of the deep groundwater between baseline (control) and development (treatment) periods.

The evaluation of this hypothesis will be similar to those described for analysis of the alluvial aquifers. Trilinear diagrams will be plotted to provide a general comparison of water types between control (baseline) and treatment (development) reporting periods. Population studies will be conducted for each chemical parameter. Using the same two sets of measurements as were used in the baseline program, discriminant analysis will be performed. Finally, correlation matrices will be calculated with subsequent factor analysis. The null hypothesis will be accepted or rejected just as described for the the alluvial aquifers.

TABLE 6.5 Monitoring Schedule and Methodology for the Deep (Upper and Lower Oil Shale Aquifers Monitoring Program, Tract C-a.

Monitoring Locations- Upper Aquifer Holes Am3 G-S M1, G-S M2, G-S M3 G-S M4, G-S 15 upper, and G-S 15 lower

Monitoring Frequency - Continuously

| Parameters | Methodology |
|---|---|
| Aquifer Water Level | Recorders |

Monitoring Locations - AM 3, G-S M1, G-S M2, G-S M3 G-S M4, G-S 15 upper, and G-S 15 lower

Monitoring Frequency - Annually (July)

| Parameters* | Methodology |
|---|---|
| Alkalinity | Titrimetric |
| Aluminum | AA |
| Ammonia | Titrimetric |
| Arsenic | Gutseit |
| Barium | Spectrographic |
| Beryllium | Spectrographic |
| Bicarbonate | Titrimetric |
| Bismuth | Spectrographic |
| Bromide | Titrimetric |
| Boron | Colorimetric |
| Cadmium | AA |
| Calcium | Titrimetric |
| Carbonate | Titrimetric |
| Chemical Oxygen Demand | Titrimatric |
| Chloride | Titrimetric |
| Chromium | AA |
| Color | |
| Conductance | Meter (F) |
| Copper | Spectrographic |
| Cyanide | Colorimetric |
| Dissolved Organic Carbon (DOC Fractionation) | Carbonaceous Analyzer (Non Standard Method) |
| Dissolved Solids, Total | Dried at 180°C |
| Fluoride | Electr[illegible] |
| Gallium | Spectro[illegible]hic |
| Germanium | Spectrogra[illegible]hic |
| Iron | Phenanthroline |
| Lead | AA |
| Lithium | Spectrograhpic |
| Magnesium | Titrimetric |
| Manganese | Spectrographic |

TABLE 6.5 Monitoring Schedule

Annual Parameters, Continued

| Parameters | Methodology |
|---|---|
| Mercury | AA |
| Molybdenum | Spectrographic |
| Nickel | AA |
| Nitrate + Nitrite | Cadmium Reduction |
| Odor | |
| pH | Paper (F) |
| Phenols | 4-AAP |
| Phosphate, Dissolved | Colorimetric |
| Potassium | AA |
| Radioactivity | |
| Gross Alpha | |
| If > 4 pci/l | Proportional Counter |
| Then $Ra^{226}$ | Alpha Particle Spectrometric |
| Natural Uranium | Fluorimetric |
| Gross Beta | |
| If > 100 pci/l | Proportional Counter |
| Then $Sr^{90}$ | Proportional Counter |
| $Ce^{137}$ | Gamaspectronmetry |
| Selenium | Fluorimetric |
| Silica | Colorimetric |
| Sodium | AA |
| Strontium | AA |
| Sulfate | Turbidimetric |
| Sulfide | Titrimetric |
| Temperature | Thermometer (F) |
| Titanium | Spectrographic |
| Vanadium | Spectrographic |
| Zinc | AA |
| Zirconium | Spectrographic |

(F) Field

* Parameters except COD, color, conductivity, odor, pH, and temperature are dissolved.

If the null hypothesis is rejected at any stage in its evaluation, an anomaly is indicated. The source of the anomaly will be analyzed through the statistical methods discussed above. This analysis will allow us to determine changes in both baseline hydrology and possible hydrologic environmental effects. If impact from development operations is indicated, appropriate mitigation measures will be taken.

The hypothesis to be tested is:

> $H_0$: There is no significant difference in the physical parameters of the deep groundwater between baseline and development periods.

Evaluation of this hypothesis will begin with an examination of conductivity, pH, temperature, and water level for each deep groundwater well. Baseline analysis revealed that the best description of the probability density function for conductivity could be calculated by using the method of non-linear lease squares, assuming a log-normal distribution. Temperature, pH, and water levels were found to be normally distributed. Estimates encompassing 99% of the expected population for each parameter at each well will be calculated from baseline data. Data collected during the development phase will then be compared with these estimates. If the values are within the expected ranges, the null hypothesis will be accepted.

Water level changes in the upper aquifer will be investigated using hydrographs, curve fittings, and residual analysis. Correlation matrices will be generated to examine the similarity of cyclic trends between holes. Data from the baseline and development reporting periods will then be compared. The null hypothesis will be accepted if similar correlations and seasonal trends are found.

If the null hypothesis is rejected at any stage in its evaluation, an anomaly is indicated. The source of the anomaly will be analyzed through the statistical methods discussed above. This analysis will determine changes in both baseline hydrology and possible hydrologic environmental effects. If impact from development operations is indicated, appropriate mitigation measures will be taken.

## 6.3 OPERATIONAL MONITORING

### A. Subsurface Disposal Permit Monitoring

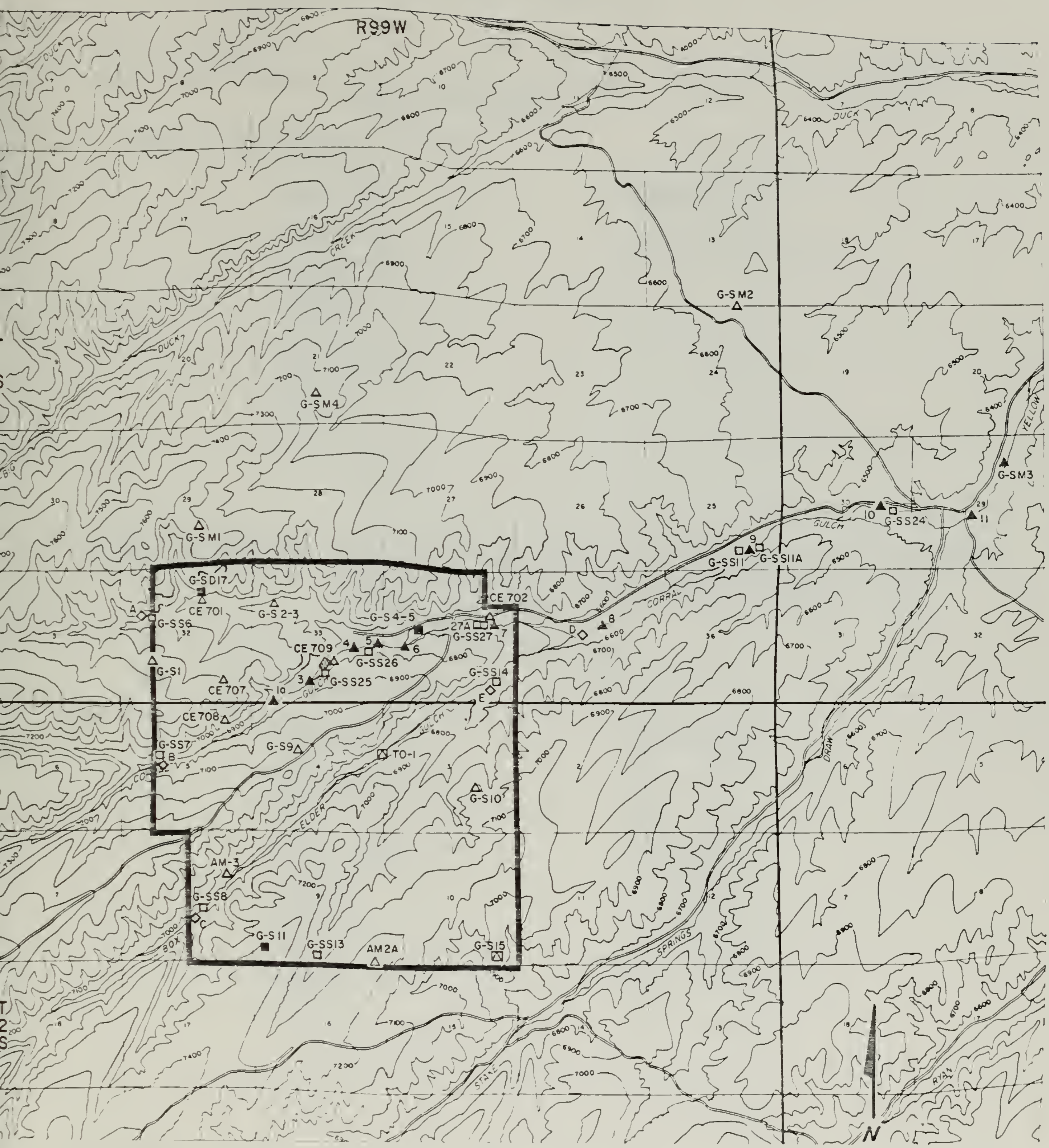
1. Objective - The objective of monitoring the water to be discharged into the aquifer as well as receiving aquifer conditions is to detect any parameters in excess of State limitations as authorized by the Subsurface Disposal Permit. Water removed from the upper aquifer will be discharged back into the upper aquifer with the ultimate goal to protect the receiving aquifer against deterioration.

2. Method - Five surface water gaging stations, eight alluvial aquifer monitoring holes, twelve upper aquifer monitoring holes, one lower aquifer monitoring hole, and the composite reinjection water (Figure 6.4) are monitored in accordance with the schedule on Table 6.6. Only the additional items over and above the hydrology program (6.1 and 6.2) are listed. At such time, when the injection program is no longer in a testing phase, this monitoring will be modified in accordance with the permit stipulations.

3. Experimental Design and Data Analysis - This program is being carried out to assure that injection occurs only in the upper aquifer and that prevention, abatement, and control of pollution to the waters of the State are being met in accordance with the Subsurface Disposal Permit. This permit is in effect for a period of five years or up to the time of the first retort burn, whichever occurs first. This will be determined by comparison of baseline water levels with MDP levels to determine if significant changes have occured.

If there are any changes not related to the baseline conditions then the Division of Health will be notified immediately. Cement bond logs will then be run to detect the particular holes causing the interconnection. Thence, appropriate remedial measures will be performed.

In the event of such a significant change, the Division of Health shall be notified immediately by phone and in writing within 24 hours. In addition, in



R99W
DUCK
CREEK
GULCH
CORRAL
ELDER
BOX
SPRINGS
STATE
DRAW
YELLOW
G-SM1
G-SM2
G-SM3
G-SM4
G-SD17
CE 701
CE 702
CE 707
CE 708
CE 709
G-S 2-3
G-S4-5
G-SS6
G-SS7
G-SS8
G-S1
G-S9
G-S10
G-S11
G-SS11
G-SS11A
G-SS13
G-SS14
G-S15
G-SS24
G-SS25
G-SS26
G-SS27
27A
TO-1
AM-3
AM2A
T
2
S
N

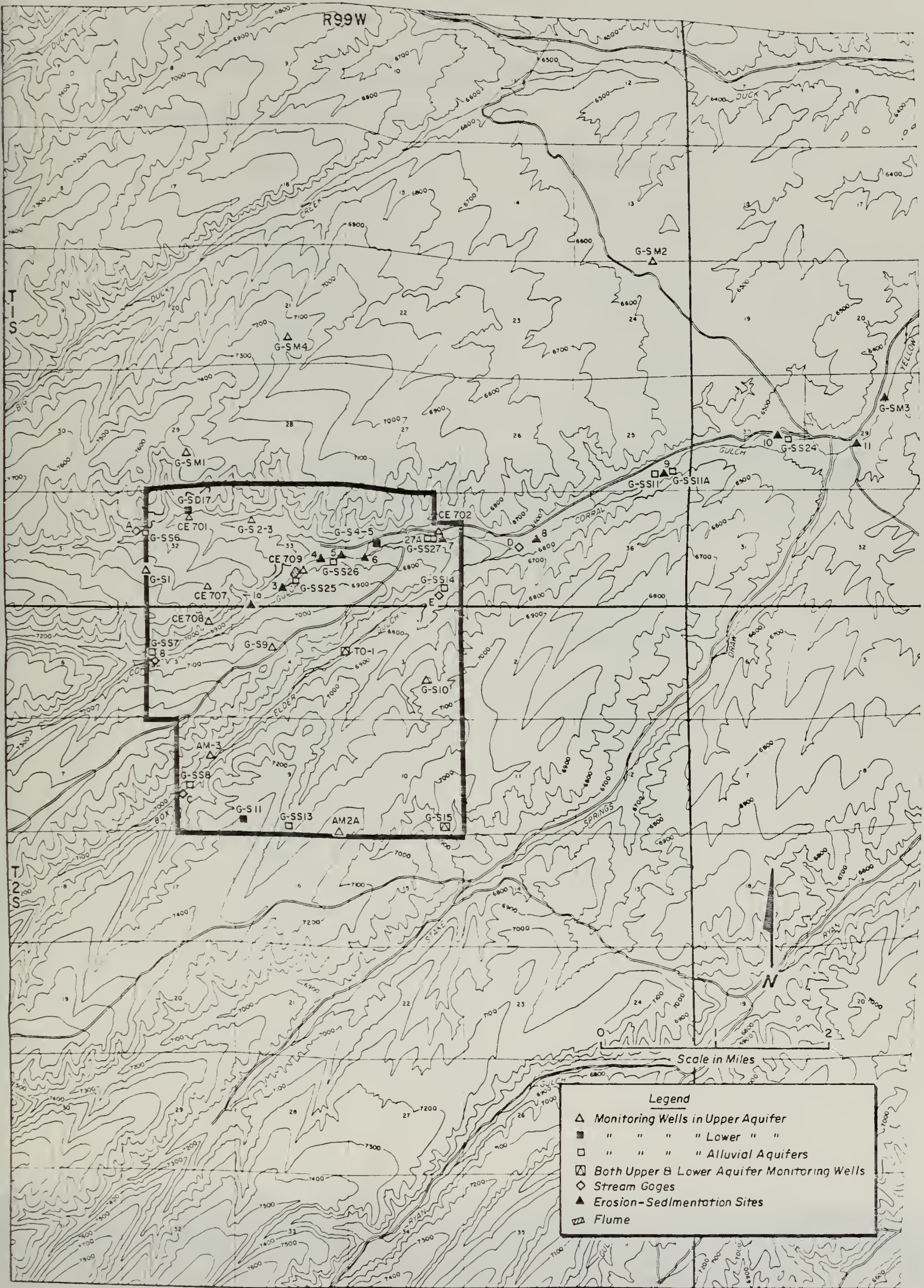



Figure 6.4. Locations of Operational Monitoring Hydrology Sampling Sites.

TABLE 6.6 Monitoring Frequencies and Methodolgies for the Subsurface Disposal Permit Program, Tract C-a

---

Monitoring Stations - USGS Stream Gages (A, B, C, D, and F) and Composite Reinjection Water

Monitoring Frequency - Monthly

| Parameters | Methodology |
|---|---|
| Alkalinity | (USGS Conducting) |
| Bicarbonate | |
| Calcium | |
| Chloride | |
| Fluoride | |
| Magnesium | |
| Silica | |
| Sodium | |
| Sulfate | |
| pH | |

---

Monitoring Stations - Alluvial Aquifer Holes (G-S S6, G-S S7, G-S S8, G-S S13, G-S S14, G-S S25, G-S S-26, and G-S S27). Upper Aquifer Holes (Am 3, G-S 15, G-S M1, G-S M2, G-S M3 and G-S M4). Lower Aquifer Hole G-S 15:

Monitoring Frequency - Monthly[1]

| Parameters | Methodology |
|---|---|
| Conductivity | Meter (F) |
| pH | Paper (F) |
| Temperature | Thermometer |
| Alkalinity | Titrimetric |
| Calcium | Titrimetric |
| Chloride | Titrimetric |
| Fluoride | EPA Approved |
| Magnesium | Totrimetric |
| Silica | Colorimetric |
| Sodium | AA |
| Sulfate | Turbidimetric |

TABLE 6.6 Monitoring Frequencies and Methodologies for the Subsurface Disposal Permit Program (Continued)

Monitoring Frequency - Annually (January)

| Parameters | Methodology |
|---|---|
| Alkalinity | Titrimetric |
| Aluminum | AA |
| Ammonia | Titrimetric |
| Arsenic | Gutseit |
| Barium | Spectrographic |
| Beryllium | Spectrographic |
| Bicarbonate | Titrimetric |
| Bismuth | Spectrographic |
| Bromide | Titrimetric |
| Boron | Colorimetric |
| Cadmium | AA |
| Calcium | Titrimetric |
| Carbonate | Titrimetric |
| Chemical Oxygen Demand | Titrimatric |
| Chloride | Titrimetric |
| Chromium | AA |
| Color | |
| Conductance | Meter (F) |
| Copper | Spectrographic |
| Cyanide | Colorimetric |
| Dissolved Organic Carbon (DOC Fractionation) | Carbonaceous Analyzer (Non Standard Method) |
| Dissolved Solids, Total | Dried at 180°C |
| Fluoride | Electrode |
| Gallium | Spectrographic |
| Germanium | Spectrographic |
| Iron | Phenanthroline |
| Lead | AA |
| Lithium | Spectrograhpic |
| Magnesium | Titrimetric |
| Manganese | Spectrographic |
| Mercury | AA |
| Molybdenum | Spectrographic |
| Nickel | AA |
| Nitrate + Nitrite | Cadmium Reduction |
| Odor | |
| pH | Paper (F) |
| Phenols | 4-AAP |
| Phosphate, Dissolved | Colorimetric |
| Potassium | AA |
| Radioactivity | |
| Gross Alpha | |
| If > 4 pci/l | Proportional Counter |
| Then Ra226 | Alpha Particle Spectrometric |
| Natural Uranium | Fluorimetric |

TABLE 6.6 Monitoring Frequencies and Methodologies for the Subsurface Disposal Permit Program (Continued)

| Parameters | Methodology |
|---|---|
| Gross Beta | |
| If > 100 pci/l | Proportional Counter |
| Then Sr90 | Proportional Counter |
| Ce137 | Gamaspectrommetry |
| Selenium | Fluorimetric |
| Silica | Colorimetric |
| Sodium | AA |
| Strontium | AA |
| Sulfate | Turbidimetric |
| Sulfide | Titrimetric |
| Temperature | Thermometer (F) |
| Titanium | Spectrographic |
| Vanadium | Spectrographic |
| Zinc | AA |
| Zirconium | Spectrographic |

Monitoring Stations - Upper Aquifer Holes (Am 2A. CE 701, CE 702 CE 705A(TO 1) CE 707, CE 709 G-S 9, G-S 10):

Monitoring Frequency - Daily

| Parameters | Methodology |
|---|---|
| Water Level | "M Scope" |

Monitoring Fequency - Monthly

| Parameters | Methodology |
|---|---|
| pH | (F) |
| Conductivity | (F) |
| Temperature | (F) |
| Alkalinity | |
| Calcium | |
| Chloride | |
| Fluoride | |
| Magnesium | |
| Silica | |
| Sodium | |
| Sulfate | |

TABLE 6.6 Monitoring Frequencies and Methodologies for the Subsurface Disposal Permit Program (Continued)

---

Monitoring Frequency - Semi Annually

| Parameters | Methodology |
|---|---|
| Alkalinity | Titrimetric |
| Aluminum | AA |
| Ammonia | Titrimetric |
| Arsenic | Gutseit |
| Barium | Spectrographic |
| Beryllium | Spectrographic |
| Bicarbonate | Titrimetric |
| Bismuth | Spectrographic |
| Bromide | Titrimetric |
| Boron | Colorimetric |
| Cadmium | AA |
| Calcium | Titrimetric |
| Carbonate | Titrimetric |
| Chemical Oxygen Demand | Titrimatric |
| Chloride | Titrimetric |
| Chromium | AA |
| Color | |
| Conductance | Meter (F) |
| Copper | Spectrographic |
| Cyanide | Colorimetric |
| Dissolved Organic Carbon (DOC Fractionation) | Carbonaceous Analyzer (Non Standard Method) |
| Dissolved Solids, Total | Dried at 180°C |
| Fluoride | Electrode |
| Gallium | Spectrographic |
| Germanium | Spectrographic |
| Iron | Phenanthroline |
| Lead | AA |
| Lithium | Spectrograhpic |
| Magnesium | Titrimetric |
| Manganese | Spectrographic |
| Mercury | AA |
| Molybdenum | Spectrographic |
| Nickel | AA |
| Nitrate + Nitrite | Cadmium Reduction |
| Odor | |
| pH | Paper (F) |
| Phenols | 4-AAP |
| Phosphate, Dissolved | Colorimetric |
| Potassium | AA |
| Radioactivity | |
| Gross Alpha | |
| If > 4 pci/l | Proportional Counter |
| Then Ra226 | Alpha Particle Spectrometric |
| Natural Uranium | Fluorimetric |

TABLE 6.6 Monitoring Frequencies and Methodologies for the Subsurface Disposal Permit Program (Continued)

| Parameters | Methodology |
|---|---|
| Gross Beta | |
| If > 100 pci/l | Proportional Counter |
| Then $Sr^{90}$ | Proportional Counter |
| $Ce^{137}$ | Gamaspectronmetry |
| Selenium | Fluorimetric |
| Silica | Colorimetric |
| Sodium | AA |
| Strontium | AA |
| Sulfate | Turbidimetric |
| Sulfide | Titrimetric |
| Temperature | Thermometer (F) |
| Titanium | Spectrographic |
| Vanadium | Spectrographic |
| Zinc | AA |
| Zirconium | Spectrographic |

Monitoring Station - Composite Reinjection Water

Monitoring Frequency - Daily

| Parameters | Methodology |
|---|---|
| Conductivity | Meter (F) |
| Flow | Meter (F) |
| pH | Meter (F) |
| Sediment | Inhoff Com (F) |
| Temperature | Thermometer (F) |

(F) Field

[1] Excluding alluvial holes for January, April, July, and October where these parameters are monitored under 6.2 of the SOW.

the event that a significant change occurs in a monitoring parameter, RBOSC shall immediately commence daily sampling. If the trend continues for seven consecutive days, RBOSC shall begin taking corrective action immediately and provide a description of that action to the Divison of Health.

B. NPDES Permit Monitoring

1. Objective - Point source discharges of water produced during drilling, pump-testing, and dewatering are monitored to detect any parameters which exceed those authorized by the State through the NPDES permit. The ultimate goal of the program is to protect existing waters against deterioration of surface water quality. Discharges authorized under this permit are expected to continue only until the subsurface injection program is fully implemented, at which time, discharges will be discontinued. This monitoring program will no longer be necessary at that time and will be discontinued automatically. RBOSC will notify the AOSO of this action.

2. Method - The direct discharge will be monitored at the flume (Figure 6.4). The frequencies, parameters, and methods (prescribed by EPA) are listed below.

---

Station: Flume

Frequency - Daily

| Parameters | Methodology |
|---|---|
| Flow | Flume |
| pH | EPA Approved |
| TSS | EPA Approved |
| TDS or Conductivity | EPA Approved |
| Oil and Grease | Visual |

Frequency - Weekly

| Parameters | Methodology |
|---|---|
| Fluoride | EPA Approved |
| Boron | EPA Approved |

The results will be reviewed to determine if they exceed the following NPDES permit limitations:

(1) Total Suspended Solids: 30 mg/1 30-day average; 45 mg/1 7-day average-daily monitoring.
(2) Total Dissolved Solids: 3000 mg/1 daily maximum, daily monitoring.
(3) Fluoride: 3.0 mg/1-daily maximum, weekly monitoring.
(4) Boron: 5.0 mg/1, weekly monitoring.
(5) Barium: No limit or monitoring.
(6) pH: Between 6.0 and 9.0 units, daily monitoring.
(7) Oil & Grease: 10 mg/1, no visible sheen, daily visual monitoring.

Permit procedures will be followed in reporting discharges which exceed the limitations.

3. Experimental Design and Data Analysis - Simple comparisons are all that are necessary for this program.

## 6.4 MDP PUMP TEST MONITORING

### A. Surface Water

1. Objective - The objective of monitoring surface water during the pumping test is to detect any impact on surface water quantity and quality from dewatering activities. The ultimate goal is to protect existing waters against deterioration in quality. This is also a short term program which will be discontinued once the testing program is completed and when approved by the AOSS.

2. Methods - The following table summarizes the location, frequency, parameters, and methodology of this program.

Monitoring Station - Surface Gage at 84 Ranch.

Monitoring Frequency: Semi-monthly

| Parameters | Methodology |
|---|---|
| Flow | Weir (F) |
| Conductivity | Meter (F) |
| pH | Meter (F) |
| Temperature | Thermometer |

---

Sample collection and analyses will be performed in accordance with procedures established in the RBOSC Quality Assurance Manual.

3. Experimental Design and Data Analysis - Population studies will be used to evaluate any changes in water quality or quantity. Associations and interrelationships between the parameters and pump discharge will be examined by means of correlation matrices.

B. Alluvial Groundwater

1. Objectives - The objective of monitoring the alluvial holes during the pumping test is to determine the impact of dewatering well discharge on water level and quality in the alluvial aquifer. The program will be discontinued once the pump test program is completed, with the approval of the AOSS.

2. Methods - The following table summarizes the location, frequency, and parameters of this program.

---

Monitoring Stations: Alluvial Aquifer Holes (G-S S-11; G-S 11-A; G-S S-24; G-S S-27; G-S S-27A)

Monitoring Frequency: Semi-monthly

| Parameters | Methodology |
|---|---|
| Water Level | Tape and M-Scope |
| Temperature | Thermometer |
| Conductivity | Meter |
| pH | Meter |

---

Sample collection and analyses will be performed in accordance with procedures established in the RBOSC Quality Assurance Manual.

3. Experimental Design and Data Analysis - Population studies will be used to evaluate any changes in water quality or quantity. Associations and interrelationships between the parameters and discharge will be examined by means of correlation matrices.

C. Erosion and Sedimentation Sites

1. Objectives - The objective of monitoring the erosion and sedimentation sites is to determine changes in stream channels downstream of operations due to pump test discharges. Once the pump test program is completed, the frequency of the erosion and sedimentation tests will be adjusted upon the approval of the AOSS.

2. Methods - The following methods will be observed.

---

Monitoring Stations: Sediment and Erosion on Corral Gulch

| | |
|---|---|
| 1A | Above discharge point |
| 3 | At G-S S25 |
| 4 | Above confluence with Dry Fork |
| 5 | Below confluence with Dry Fork |
| 6 | One-third mile below confluence with Dry Fork |
| 7 | At G-S S27 |

8 At USGS Gaging Station Corral Gulch east of Tract C-a

9 At G-S S11

10 At G-S S24

11 At County Road 24

| Parameter | Methodology |
|---|---|
| Channel Cross-Section Measurements | Tape Measure |

A total of ten erosion and sedimentation stations have been established. The data to be collected at these stations consists of a channel cross-section. A profile will be made by taking channel depth measurements to the nearest 0.5 inch every six inches across the stream channel. The channel width will be sufficient to contain all anticipated flows. In addition, photographs will be taken both upstream and downstream from the point of the profile. Additional sections will be measured two times a month.

3. Experimental Design and Data Analysis - The cross-sectional profiles will be compared to detect aggradation or degradation of the stream channel

D. Deep Groundwater

1. Objectives - Static water levels are measured at four additional upper aquifer holes and five additional lower aquifer holes weekly. The purpose is to determine that the water level trends continue according to the trends established in the past.

2. Methods - These data will be collected using "M Scopes" and will be plotted on hydrographs. Locations and parameters are described below:

---

Monitoring Stations - Upper Aquifer Monitor Holes CE 708, G-S 1, G-S 2-3, and G-S 11 and Lower Aquifer Monitor Holes CE 702, CE 709, G-S D17, G-S 4-5 and TO 1

Monitoring Frequency - Weekly

| Parameter | Methodology |
|---|---|
| Water Level | M-Scope |

3. Experimental Design and Data Analysis - The data collected from this program will be plotted on hydrographs and compared to the previous data. If there are no major differences from the previous trends then no further action will be initiated. However, if new trends appear evident from the data then the monitoring frequency will be increased to verify the nature of the trend and the data analyzed to determine the cause. Corrective measures will then be initiated.

E. Additional Monitoring, As Required

At any of the surface or groundwater sites mentioned above, should the pH be found to vary for three consecutive days by 1-1/2 units from established baseline values, then major and minor constituents will be analyzed. Also, if conductivity is found to vary plus or minus 20 percent for three consecutive days, major and minor constituents will be analyzed.

At any of the erosion and sedimentation stations, should the stream channel be drastically changed, additional measurements will be taken in consultation with the AOSS.

F. Water Contained In Impoundments

1. Objectives - Water which accumulates and/or is stored in surface water impoundments will be monitored to determined if this water will present any environmental hazards in the event of its escape into surface or ground water sources, or its consumption by wildlife.

2. <u>Methods</u> - Impoundments on Tract C-a will be used for storage of various sources of water as shown in Figure 6.5. The design for these ponds and the proposed monitoring program reflect the projected quality of the water which will be stored therein. Detailed design plans for the various ponds have been submitted to and approved by the AOSS and/or the State. Basically, the ponds are designed as described below:

- <u>West Retention Pond</u> - used to retain relatively clean water from service area runoff and mine dewatering. It is built to the specifications of the Division of Water Resources, Colorado Department of Natural Resources.

- <u>East Retention Pond</u> - used to retain water from boiler and sewage treatment plant and process area runoff. It is built in conformance by the previously mentioned specifications. Seepage will be monitored by piezometers and subsidence markers will be used to detect failure of berm foundations for both the West and East Retention Ponds.

- <u>Retort Water and Scrubber Ponds</u> - used to store poor quality water (from retorts and scrubbers). Retort water pond will be lined with a 30 mil thick layer of plastic. A perforated plastic pipe will be installed between two layers of the 30 mil plastic layer at the lower edge of the pond to collect any leachate. The scrubber retention ponds will be of similar construction to the retort water pond, except that a 10 mil liner will be used and both liners around the collection point will be 10 mil thick. Each pond will contain a discrete leak detection system. Ponds will be inter-connected to allow for controlled overflow, and they will be surrounded by diversion ditches.

The design of these pond systems is expected to prevent any escape of harmful substances into surface and groundwater sources. Nonetheless, water within these impoundments will be monitored to provide data on the chemical constituents which it contains. Parameters to be monitored for each type of impoundment and the frequency of analysis is described in Table 6.7. Should the quality of the water within an impoundment prove to be potentially hazardous to wildlife, measures will be taken to reduce or prevent its consumption.

G. Impoundment Seepage

1. Objectives - The potential seepage of water from retention ponds will be monitored to determine if retained water is escaping into surface or ground water sources.

2. Methods - Such seepage will be monitored by one of two methods:

- o Measurements of changes in water levels in alluvial holes or piezometers located downgradient from potential sources (west retention and east retention ponds)
- o Observations of water accumulation in leak detection system from plastic lined ponds (retort water and scrubber blowdown ponds).

Additionally, the suspected seepage water found in alluvial and piezometer holes and the seepage detection systems will be monitored for quality (as volume permits) on a regular basis (Table 6.8). Quality of water in downgradient alluvial or piezometer holes will be monitored as volume permits following any detected leak to verify its source. Quality of suspected leakage water will be compared with source impoundment water to verify the source whenever leakage is suspected. If leakage is verified, monitoring will be increased and appropriate mitigation measures will be taken, in consultation with the AOSO.

Table 6.7. Sampling Schedule for Measurement of Impoundment Water Quality, Tract C-a.

| Frequency/ Parameters | Impoundment: West Retention Pond | East Retention Pond | Retort and Scrubber Blowdown Ponds |
|---|---|---|---|
| Continuous/Daily | | | |
| Input flow | | | X[1] |
| Conductivity | X | X | X |
| Temperature | X | X | X |
| pH | X | X | X |
| Quarterly | | | |
| Major and minor ions[2] | X | X | X |
| Semi-annually[3] | | | |
| Trace metals | X | X | X |
| Phenols | X | X | X |
| Radioactivity | X | X | X |
| Other | X | X | X |

[1]Indirect flow measurements only for retort water pond

[2]$NH_4$, Ca, Cl, F, Fe, Mg, $NO_2$ and $NO_3$, $SO_4$, P, K, B , hardness, Si, Na

[3]See semi-annual parameters listed for alluvial holes (pp. 118-120)

Table 6.8. Sampling Schedule for Measurements of Seepage Water Quality, Tract C-a

| Frequency/ parameters | Seepage Monitor Source: Alluvial and Piezometer Holes | Seepage Monitor Source: Leakage Collection system |
|---|---|---|
| Weekly | | |
| Water level changes | X | |
| Water accumulation | | X (daily) |
| When water observed | | |
| Conductivity | | X |
| Temperature | | X |
| pH | | X |
| Major, minor ions[1] | | X |
| Quarterly[2] | | |
| Conductivity | X | |
| Temperature | X | |
| pH | X | |
| Major, minor ions[1] | X | |
| Semi-annually[2,3] | | |
| Trace metals | X | |
| Phenols | X | |
| Radioactivity | X | |
| Other | X | |

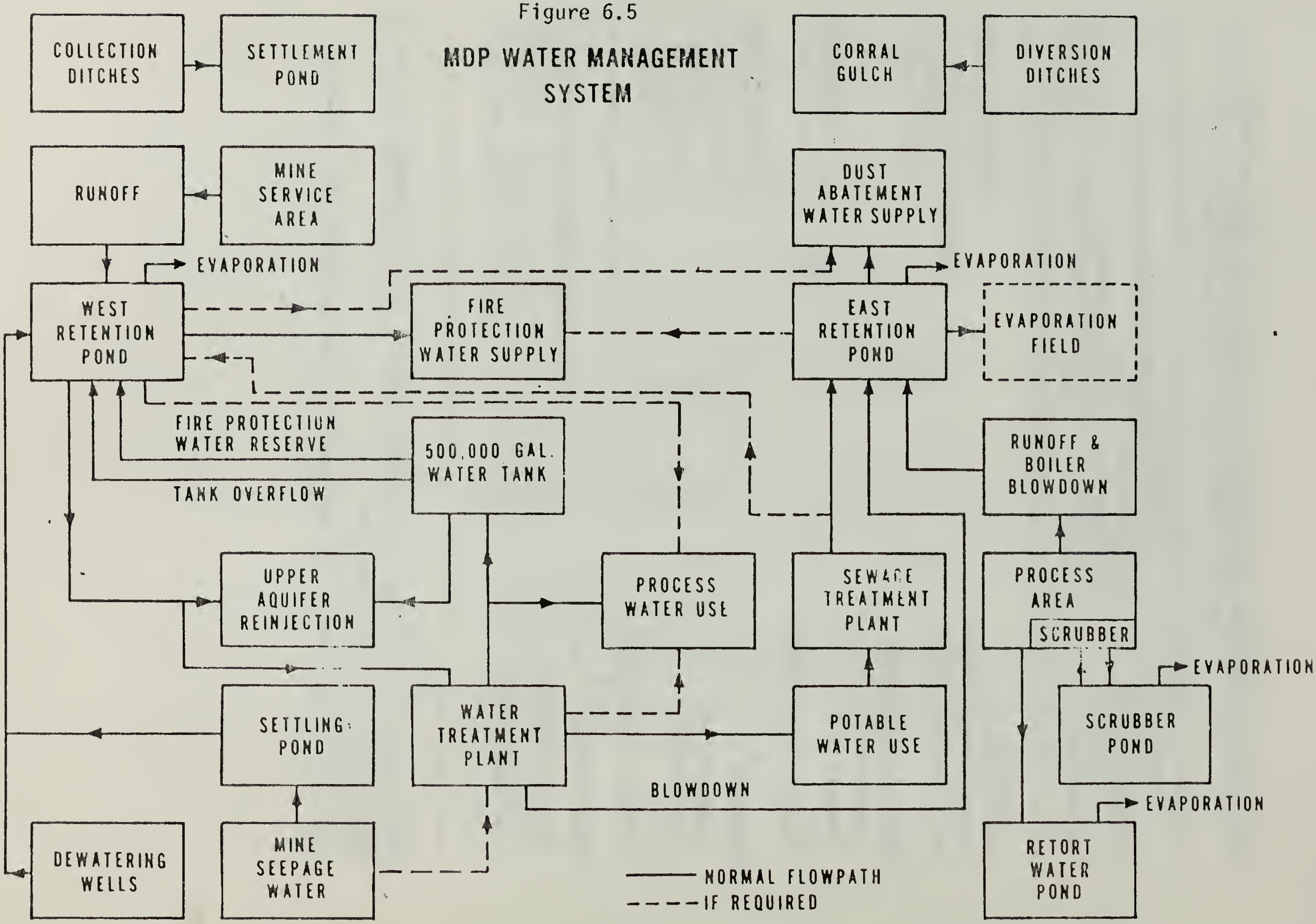
[1] $NH_4$, Ca, Cl, F, Fe, Mg, $NO_2$ and $NO_3$, $SO_4$, P, K, B, hardness, Si, Na

[2] When sufficient water present

[3] See semi-annual list of parameters for alluvial holes (pp. 118-120)

Figure 6.5

**MDP WATER MANAGEMENT SYSTEM**



H. Raw Ore Leachate Sampling

1. Objectives - The leachate from MDP raw shale disposal piles will be collected and analyzed to determine the quality of any runoff.

2. Methods - Leachate will be collected above a sheet of plastic lining which has been buried in the raw shale pile. Plastic PVC pipe diverts accumulated water to the edge of the pile where it collects in a catchment basin. Once sufficient quantities of leachate are accumulated, water samples are collected and analyzed according to AOSO specifications.

## 6.5 Special Studies

### A. Sediment Characterization Studies

1. Objectives - The objective of the sediment charterization study is to determine the change in the physical and chemical characteristics of the stream sediments. However, the acquisition of meaningful results for studies of this nature is extremely difficult. RBOSC, therefore, proposes to conduct the program once initially, and thereafter only if the usefulness of the data can be demonstrated.

2. Methods

a. Parameters - Analysis for the following physical and chemical characteristics of the sediment will be conducted:

- grain size (screen analysis to a minimum of 7 fractions)
- Mineralogic examination (microscopic)
- x-ray diffraction (bulk sediment and clay mineral matrix)
- spectroscopic analysis (trace metals)
- cation exchange capacity

Additional analysis will be run for the trace elements which are identified in significant quantities in the spectrographic analysis and which may be harmful to aquatic organisms.

b. Monitoring Location - The samples for sediment characterization will be collected upstream from the gaging station located at Corral Gulch east of Tract C-a (USGS I.D. No. 09306242). Sediment samples will be collected in an area of deposition near the point where the biological, water quality, and suspended sediment samples are collected.

c. Monitoring Frequency and Schedule - Sediment samples will be collected once initially during a low flow period of the year. Sediment sampling will be scheduled to coincide with one of the water quality and biological sampling periods.

d. Sample Collection and Analysis - Samples will be collected using a BMH-53 sediment sampler or equivalent. Only the upper inch of sediment will be retained for the analysis (Guy and Norman 1970). A composite sample will be prepared from the individual samples collected at the station. Samples will be uniformly spaced across the stream.

A minimum of six individual samples will be collected for the composite sample. Each individual sample will be placed in a separate container, for compositing at the laboratory. Information recorded on the container will include:

- Station name
- Date
- Carton number
- Time
- Gage height

- Water temperature
- Bed form and flow conditions
- Kind of sampler used
- Special instruction for analysis and computation
- Initials of collector

Adequate samples will be collected so that a portion of the sample can be preserved for future study, if needed. During the initial sampling period a minimum of six composite samples will be collected and analyzed. The replicates will be analyzed to determine the natural variability of the sediment characteristics at the station. The methods to be used in the chemical and physical characterization of the sediments are listed in Table 6.9. Detection limits are included, where appropriate.

3. Experimental Design and Data Analysis - Data collected from the sediment characterization will be compared with baseline sediment data for the area, with physical and chemical data for soils and subsoils, and with previous data collected at the sampling station.

If potentially harmful concentrations of a substance are found in the sediments, the sources of the material will be investigated. Tests will be conducted to determine the levels of that substance in the exposed materials from tract-related activities.

Table 6.9 Sediment Characterization Program (Laboratory Analysis)

| Type of Analysis | Method | Detection Limit (ppm) (where appropriate) |
|---|---|---|
| Grain size | Screen analysis | |
| Mineralogic matrix | x-ray diffraction | |
| Mineralogic examination | Petrographic microscope | |
| Trace Elements | Emissionn spectrographic analysis | |
| Ca | " | 200 |
| Fe | " | 500 |
| Mg | " | 200 |
| Ag | " | 1 |
| As | " | 500 |
| B | " | 10 |
| Ba | " | 10 |
| Be | " | 2 |
| Bi | " | 10 |
| Cd | " | 50 |
| Co | " | 5 |
| Cr | " | 10 |
| Cu | " | 2 |
| Ga | " | 10 |
| Ge | " | 20 |
| La | " | 20 |
| Mn | " | 10 |
| Mo | " | 2 |
| Ni | " | 5 |
| Nb | " | 20 |
| Pb | " | 10 |
| Sb | " | 100 |
| Sc | " | 10 |
| Sr | " | 100 |
| Sn | " | 10 |
| Ti | " | 20 |
| V | " | 10 |
| W | " | 50 |
| Y | " | 10 |
| Zn | " | 200 |
| Zr | " | 20 |
| Cation exchange capacity | Sodium acetate or ammonium acetate method | |

## Literature Cited


Colorado School of Mines Research Institute. 1976. An evaluation of the soils of Tract C-a and adjacent areas. Prepared for Rio Blanco Oil Shale Project.

Dixon, W. J., University of California Press. 1975. Biomedical Computer Programs.

Guy, H. P., and V. W. Norman. 1970. Field methods for Measurement of Fluvial Sediment. U.S. Geological Survey Techniques of Water Resources Investigation BK. 3 Ch. 22.

Nie, Norman H., Hull, C. Hadlai, Jenkins, Jean G., Steinbrenner, Karin, and Bent, Daleh. McGraw-Hill, 1975. Statistical Package for the Social Sciences (SPSS).

RBOSP. 1977. Final Environmental Baseline Report for the Rio Blanco Oil Shale Project. Vol. 1 Ch. 3 - Sediment Chemistry. Gulf-Standard, Denver, Colorado.

# 7.0 SPECIAL STUDIES

## 7.1 TOXICOLOGY

Initiation of site specific toxicology studies must await availability of processed (waste) shale, and shale oil produced during Tract C-a retorting activities. These materials will not be available until after the first retort burn, scheduled for 1979.

The American Petroleum Institute (API) is now actively involved in toxicology research on oil shale products and by-products produced from surface retorts. There is a very good possibility that their efforts will be applicable to the Tract C-a materials. Therefore, RBOSC's toxicology program will be designed to investigate the applicability of the API work, and to initiate additional site specific studies, if necessary.

### A. Objectives

The objectives of the toxicology research for Tract C-a will include determination by quantitative chemical analysis the similarity of Tract C-a raw shale ore, processed shale and shale oil to materials currently being studied by the API and to investigate potential sources of ground water contamination from RBOSC in-situ retorts.

### B. Methods

1. Parameters - Parameters to be studied will include fluorides, toxic heavy metals, radioactivity, free silica, and polynuclear aromatic content of raw shale, processed shale, and shale oil produced from Tract C-a in-situ retorts. Processed shale will also be analyzed for total benzene extractables, water extractables, and benzene extract of water extractables.

2. Analytical Techniques - Trace metals will be examined by spark source mass spectrophotometry, and silicon dioxide will be analyzed by X-ray diffraction techniques; oils and resins will be distilled and examined for parafins, olefins, naphthenes, and aromatics. Nuclear magnetic resonance techniques will be used to classify aromatic hydrocarbons.

3. Data Handling and Quality Assurance - Analyses will be conducted by qualified chemists using accepted EPA and APHA Standard techniques. The testing program will be conducted according to documented quality assurance procedures with regularily scheduled quality control checks.

C. Experimental Design and Data Analyses

Analytical data from the Tract C-a retort materials will be compared with materials under study by the API. If API materials do not differ significantly from RBOSC materials, the toxicology test data will be accepted for use by RBOSC in establishing health and safety techniques and worker exposure limits. Should the test results indicate that RBOSC materials are significantly different from API materials, then additional toxicology testing will be initiated to determine toxicity of Tract C-a materials. The extent and nature of these studies will be determined once the analytical data are available.

## 7.2 REVEGETATION/RECLAMATION

In 1975 RBOSC initiated a 3-year experimental revegetation program to demonstrate the feasibility of reclaiming disturbed oil shale lands. Since the initiation of these studies, the Department of Interior and other agencies have funded a number of experimental programs through universities and industry to investigate this problem. On-going research includes reclamation of disturbed lands, reclamation over processed shale by use of artificial soil profiles, genetic selection of suitable native plants to enhance reclamation, studies on the effects of disturbance on soil microorganisms and mycorrhizal fungi and associated recovery rates, effectiveness of irrigation, mulching, and fertilization on disturbed lands, and processed shale recovery plots and many more. RBOSC hopes to work closely with these researchers in hopes of benefiting from their work and in planning any additional experimental work for Tract C-a.

A. Objectives

The objectives of the RBOSC revegetation efforts are to: utilize research data from on-going reclamation research to evaluate future study needs for Tract C-a; to assess the success of our current experimental program over time and in compliance with lease requirements to demonstrate the feasibility of reclaiming the disturbed areas; and to assure prompt reclamation of disturbed surfaces in compliance with Colorado Mine Land Reclamation Board and AOSS requirements.

B. Methods

The RBOSC Reclamation/Vegetation Studies Supervisor will maintain close contact with private and university researchers involved in revegetation studies in the west, specifically oil shale areas. RBOSC will evaluate on-going research to determine its applicability to the Tract C-a situation and will report the results of this evaluation in the semi-annual reports. Additionally, RBOSC will assess the success of our experimental revegetation studies and will compare these results with results forthcoming from other research efforts. The experimental design and monitoring techniques for the RBOSC experimental revegetation program are described in the NUS Revegetation Studies Scope of Work dated October 8, 1975. Evaluation of experimental plots will be made annually as per the methods described in that document.

On-going reclamation of disturbed lands will be scheduled as quickly as possible following cessation of disturbance in compliance with permit and lease stipulations. Successful revegetation of small disturbed areas will be evaluated annually by determining cover by species and total cover using quadrant samples along a line transect. All activities will be designed to provide rapid stabilization and long-term recovery of disturbed areas which will achieve approval from the Colorado Mined Land Reclamation Board and the AOSS. Long term monitoring of the ultimate raw and process shale disposal piles is summarized in Table 7.1.

## 7.3 SUBSIDENCE MONITORING

1. Objectives - Subsidence monuments will be installed and measured on a periodic basis to determine if any surface displacement occurs due to the dewatering effort, the burning of the retorts, or from any other unforeseen cause.

2. Methods

a. Parameters - A survey monument grid will be placed on the ground surface over the MDP retort area prior to its rubblization. Additional monuments will be placed in various other areas to determine the effects of dewatering. The coordinates and elevation of each of the monuments will be recorded. RBOSC will determine the horizontal and vertical relationship of these monuments to a benchmark sufficiently distant from the retorts to assure that the benchmark does not itself undergo any horizontal or vertical displacement. Topographic maps at 1" = 200' and a 5-foot contour interval are currently available for the retort area. If substantial subsidence is detected by appreciable movement of the monuments, the topography of the subsided area will be mapped in appropriate detail by plane table or other suitable means. Third order surveying accuracy control will be used for all vertical and horizontal control work.

The monument will be a one-inch rebar pin anchored with resin inside a three-inch casing.

Table 7.1 Summary of the Monitoring Program for Ascertaining Successful Revegetation of Raw and Processed Shale Disposal Sites.

| Samplings Program | Parameter | Sampling Frequency | Sampling Technique | Sampling Intensity | Data Analyses |
|---|---|---|---|---|---|
| VEGETATION | Species Composition | Before Revegetation, Year 3,5... | Quadrat (9.6 sq ft) | 1 Transect/4ha (10 acres) (10 quadrats each - 10m intervals) | Coefficient of Community (CC) Percent Similarity (PS) (Pielou, 1974) |
| | Percent Cover | Before Revegetation, Year 3,5... | Quadrat (9.6 sq ft) | 1 Transect/4ha (10 acres) (10 quadrats each - 10m intervals) | Coefficient of Community (CC) Percent Similarity (PS) (Pielou, 1974) |
| | Productivity & Utilization | Before Revegetation, Year 3,5... | Double sampling method (USDA, 1970) | 1 Transect/4ha (10 acres) (10 plots each) | Analysis of Variance (AOV); Multiple Range Test |
| | Browse Condition & Utilization | Before Revegetation, Year 3,5... | Cole (1963) | 1 Transect/4ha (10 acres) (25 individual) | Analysis of Variance (AOV); Multiple Range Test |
| SOILS | pH<br>Macronutrients (N,P,K)<br>Micronutrients (Cl, Ca, Na)<br>Conductivity | Year 1,3,5... | Soil cores - (0-10cm;30-40cm) | 1 sample/4ha (10 acres) | Qualitative<br>Analysis of Variance (AOV); Multiple Range Test |
| | Trace elements (Ar, B, Zn, Se, etc.) | Year 1,3,5... | Soil cores - (0-10cm;30-40cm) | 1 sample/4ha (10 acres) | Analysis of Variance (AOV); Multiple Range Test |
| FAUNA | Small Mammals<br>Species Composition<br>Index of Abundance | Before Revegetation, Year 1,3,5... | Pit trapping<br>Live trapping | 5 Transects/unit (2 transects of 10 traps/group)* | Regression Analysis; F-test; Analysis of Variance (AOV) (Index of Abundance) |
| | Avifauna<br>Species Composition<br>Map of Territories<br>Density of Breeding Birds | Before Revegetation, Year 1,3,5... | Breeding bird mapping technique (Graul, 1976; Hall, 1964; Robbins, 1970) | 12-45 ha(30-105 acres) (depending on size of area) divided into 1 ha subunits; 8 replicates of subunits * | Regression Analysis; Analysis of Variance (AOV) (for density only) |

* Adequate sample size will be determined during the first year.

A check will be made on the original subsidence monument survey. Primary vertical control will be established at a central point. This point will be located fairly close to the site and will be on the other side of the fault which runs from NW to SE through the area. It is believed that this location will be as stable as can be found since subsidence occuring in the retort area would probably not carry through the fault.

A secondary vertical control point will be established at the intersection of the old Airplane Ridge Road with the main access road. The purpose of this point will be to reduce the time required for routine checking of the monuments, since it is considerably closer to the site than the primary control point. If, during the routine checks, subsidence is noted, then a check from primary control would be necessary to insure that secondary control had not settled as well.

Horizontal control traverses will be run through all the monuments to establish coordinates.

b. Monitoring Locations - The locations of thirty-two subsidence monuments placed to-date are shown on Figure 7.1 (see map pocket) dated July 1978. The coordinates of these monuments are listed in Table 7.1.

Additional monuments which will be required above the retorts and in the general shaft area will be established after surface construction is complete.

c. Monitoring Frequency and Schedule - The horizontal and vertical locations of monument points will be established during initial surveys. Subsequent surveys will indicate whether monuments have moved downward and hence whether subsidence has occurred. These will be performed at least every six months. The actual monitoring schedule will be highly dependent on weather conditions, especially in the winter.

Table 7.2. Locations of Subsidence Monuments, Horizontal & Vertical Control, Tract C-a

| Monument Number | Coordinates North | Coordinates East | Elevation 3/3/78 |
|---|---|---|---|
| A-1 | 226,137.48 | 156,085.20 | 6909.49 |
| A-5 | 226,041.76 | 156,759.43 | 6911.04 |
| A-20 | 225,780.75 | 158,251.04 | 6942.28 |
| A-21 | 225,782.96 | 158,354.45 | 6941.15 |
| A-22 | 225,809.69 | 158,450.95 | 6942.24 |
| A-23 | 225,841.33 | 158,547.94 | 6942.69 |
| A-24 | 225,874.83 | 158,642.68 | 6938.03 |
| A-25 | 225,895.01 | 158,738.67 | 6941.39 |
| A-26 | 225,923.70 | 158,834.38 | 6940.46 |
| A-27 | 225,951.60 | 158,930.47 | 6940.29 |
| A-28 | 225,979.43 | 159,026.70 | 6938.79 |
| | | | |
| B-1 | 226,800.29 | 157,112.65 | 6854.09 |
| B-3 | 226,432.73 | 157,004.78 | 6885.64 |
| B-5 | 226,278.26 | 157,024.02 | 6907.77 |
| B-6 | 226,109.87 | 156,944.65 | 6911.09 |
| B-7 | 225,974.03 | 156,971.63 | 6913.01 |
| B-11 | 225,614.44 | 156,885.05 | 6954.40 |
| B-12 | 225,318.64 | 156,849.75 | 6972.44 |
| B-13 | 225,110.66 | 156,813.98 | 6989.90 |
| BC-1 | 226,814.06 | 157,357.33 | 6855.55 |
| | | | |
| C-1 | 226,837.97 | 157,726.25 | 6857.01 |
| C-3 | 226,416.36 | 157,652.05 | 6910.19 |
| C-11 | 225,409.72 | 157,475.84 | 6976.53 |
| C-12 | 225,213.43 | 157,442.10 | 6993.97 |
| C-13 | 225,016.64 | 157,406.30 | 7011.18 |
| | | | |
| D-1 | 226,750.72 | 158,126.12 | 6862.93 |
| D-6 | 225,914.68 | 158,072.36 | 6920.26 |
| D-9 | 225,618.90 | 158,019.39 | 6957.08 |
| D-10 | 225,518.92 | 157,988.58 | 6968.60 |
| D-11 | 225,322.64 | 157,967.82 | 6995.22 |
| D-12 | 225,126.88 | 157,933.82 | 7016.86 |
| D-13 | 224,930.02 | 157,898.05 | 7036.72 |

3. Experimental Design and Data Analysis -

During and after the completion of the burn, and during dewatering-reinjection, the position of the monuments of the grid will be monitored in accordance to 2C. When it becomes apparent that the detectable disruption of the surface has taken place, the topography of the surface will be re-mapped to establish the pattern of subsidence. During the burn of the retorts of the MDP, RBOSC will quantify any surface subsidence that may occur. From present MDP plans and from what is known of the rocks in the mine area, measurable surface subsidence appears to be highly unlikely.

## 8.0 ECOSYSTEM INTERRELATIONSHIPS

In their development monitoring program, C-b Shale Oil Venture clarified the following point:

"Ecosystem interrelationships are not monitored or measured directly. They are inferred from three principal techniques: expert judgement resulting from baseline observations of two or more variables, correlative statistics and predictive ecosystem modeling" (C-b Shale Oil Venture, July 1978). C-b has applied this reasoning by utilization of expert judgement to develop an "effects matrix" which identifies direct and indirect effects of oil shale development and flags interrelationships of particular concern. This approach is similar to the techniques applied by RBOSC in their "cause-effect matrix," except that C-b made no attempt to quantify the interrelationships by the Leopold, et al., (1971) ranking process which was used by RBOSC. In evaluating effects of development on Tract C-a., RBOSC identified and described all potential impact activities (a total of 49) and listed them across the top of the matrix (Table 8-1).

Ecosystem components likely to be affected by these causative factors were identified (from baseline data correlations and other analysis, the literature, and professional experience) and listed down the side of matrix (Table 8-2). Qualification of impacts was attempted by assigning two ranked values to each matrix intersect or "cause-effect relationship." The first value was a ranking of the importance of the effect. The second value ranked the effect as it applied to the Tract C-a situation. Rankings were applied as follows:

| Importance | Severity/Magnitude |
|---|---|
| 1-None, not applicable | 1-None, not applicable |
| 2-Slightly important | 2-Slighty severe, small |
| 3-Moderately important | 3-Moderately severe, medium |
| 4-Very important | 4-Very severe, large |
| 5-Extremely important | 5-Extremely severe, quite large |

TABLE 8.1. Projected "Causative Factors" Or Impact Generators Which Could Impact The Tract C-a Environment During Development

**Construction**

Mine surface facilities
Surface Retorts
Underground retorts
Support facilities
Powerlines
Pipelines
Conveyor belts
Impoundments
Roads
Steam generator
Compressors
Evaporation ponds, catchment basins
Dewatering network
Cumulative construction

**Storage and Transfer**

Run-of-mine ore
Construction materials
Oil, gas, diesel fuel
Chemicals
Machinery
Explosives
Feedstocks
Soil
By-products/waste
Product oil

**Human Activity**

**Abandonment**

**Operations**

Mine ventilation
Blasting
Dewatering/reinjection
Underground retorting
Surface retorting
Compressing
Emissions

**Disposal**

Processed shale
Product, Mine seepage water
Sewage
Trash, wastes
By-products
Cumulative disposal actions

**Environmental Monitoring**

Atmospheric sampling
Groundwater monitoring
Surface water monitoring
Aquatic biota sampling
Vegetation sampling
Faunal sampling
Soil studies

**Environmental Mitigation**

Subsidence control
Habitat enhancement
Revegetation

TABLE 8.2 Listing of Ecosystem Components That Could Potentially Be Affected by Development of Tract C-a

**Atmospheric**

Precipitation chemistry
Particulate concentrations
Gaseous concentrations
Ozone levels
Temperature
Relative humidity
Visibility
Noise levels

**Groundwater**

Quantity
Quality
Flow, movement
Recharge/discharge
Level
Availability/Consumption

**Surface Water**

Quantity
Quality
Flow, velocity
Drainage basin characteristics
Sediment load
Temperature
Stream bed
Springs and seeps
Sediment chemistry

**Soils**

Erosion potential
Physical characteristics
Chemical characteristics
Trace metals

**Topography**

Slope aspect
Drainage patterns
Terrain stability

**Vegetation**

Productivity
Range condition
Community composition
Distribution
Trace metal content
Cover, density
Browse condition

**Small Mammals**

Relative abundance
Species composition
Distribution

**Large Mammals**

Relative abundance
Distribution
Migration patterns

**Predatory Mammals**

Relative abundance
Species composition
Distribution

**Reptiles and Amphibians**

Relative abundance
Species composition
Distribution

**Avifauna**

Relative abundance
Species composition
Distribution
Migration patterns

**Invertebrates**

Relative abundance
Species composition
Distribution

**Plankton**

Relative abundance
Species diversity
Habitat
Productivity

**Periphyton**

Relative abundance
Species diversity
Habitat
Productivity

**Benthos**

Relative abundance
Species diversity
Habitat

**Fishes**

Relative abundance
Species diversity
Distribution
Food habitats
Condition
Habitat

Ranking criteria were carefully delineated and provided to the professionals who participated in the ranking procedure. Importance criteria addressed the longevity of the impact, sensitivity of species potentially affected (e.g., rare or threatened), complexity of effect, degree of public concern, potential effects of human health, and economic importance of the impact. Severity/Magnitude criteria provided for consideration of areal extent of the impact and cumulative effects.

All impacts which were scored 3/3 or higher in the MDP matrix analysis were classified as potentially important and were included in the preliminary monitoring program (Table 8-3). However, as pointed out by C-b, "Two basic questions should be answered in designing a monitoring program. The first is what to monitor, and the second, how to monitor it'. The fundamental objective of a monitoring program should be to maximize the amount of useful, relevant information while minimizing the cost required to get that information" (C-b Shale Oil Venture, 1974-76 Final Report, Vol. 5, p. 141). C-b used three criteria for selecting parameters for inclusion in their monitoring program:

1. relatabiltiy to oil shale development
2. observability,
3. measurability

These are essentially the same criteria utilized by RBOSC. Impacts were related to development activities during the "cause-effect" matrix analysis. Observability, as a function of measurability was addressed by RBOSC through a second matrix analysis (Table 8-3).

The second matrix, the measurability matrix, was designed to complete the process of selecting monitoring parameters. Rankings for the measurability matrix were based on baseline data analysis, professional experience, and review of baseline data. Only those impacts which

Table 8.3. Measurability Matrix[1] For Significant (Rank of 3/3 Or Higher on Cause Effect Matrix) Modular Development Impacts[2]

| Affected Parameters | Underground retort construction | Cumulative construction activities | Dewatering and reinjection | Atmospheric venting | Storage of raw shale ore | Storage of topsoil | Habitat modification | Revegetation |
|---|---|---|---|---|---|---|---|---|
| | Source of Impact | | | | | | | |
| **Groundwater** | | | | | | | | |
| Quantity | $\frac{3/3}{4}$ | $\frac{3/3}{4}$ | $\frac{3/4}{4}$ | | | | | |
| Quality | $\frac{3/3}{5}$ | $\frac{3/3}{5}$ | $\frac{3/4}{5}$ | | | | | |
| Flow | $\frac{3/3}{4}$ | $\frac{3/3}{4}$ | $\frac{3/4}{4}$ | | | | | |
| Recharge, discharge | $\frac{3/3}{4}$ | $\frac{3/3}{4}$ | $\frac{3/4}{4}$ | | | | | |
| Level | $\frac{3/3}{5}$ | $\frac{3/3}{5}$ | $\frac{3/4}{5}$ | | | | | |
| Availability | $\frac{3/3}{4}$ | $\frac{3/3}{4}$ | $\frac{3/4}{4}$ | | | | | |
| **Surface Water** | | | | | | | | |
| Quantity | $\frac{4/3}{4}$ | $\frac{4/3}{4}$ | $\frac{3/3}{4}$ | | | | | |
| Quality | $\frac{4/3}{5}$ | $\frac{4/3}{5}$ | $\frac{3/3}{5}$ | | | | | |
| Flow, velocity | $\frac{4/3}{4}$ | $\frac{4/3}{4}$ | $\frac{3/3}{4}$ | | | | | |
| Sediment load | $\frac{4/3}{4}$ | $\frac{4/3}{4}$ | $\frac{3/3}{4}$ | | | | | |
| Temperature | $\frac{4/3}{5}$ | $\frac{4/3}{5}$ | $\frac{3/3}{5}$ | | | | | |
| Springs | $\frac{4/3}{4}$ | $\frac{4/3}{4}$ | $\frac{3/3}{4}$ | | | | | |
| Sediment chemistry | $\frac{4/3}{5}$ | $\frac{4/3}{5}$ | $\frac{3/3}{5}$ | | | | | |
| **Soils** | | | | | | | | |
| Erosion potential | | | | | | | | $\frac{3/3}{1}$ |
| Physical characteristics | | | $\frac{3/3}{3}$ | | | | | |
| Chemical characteristics | | | $\frac{3/3}{3}$ | $\frac{3/3}{2}$ | $\frac{3/3}{3}$ | $\frac{3/3}{1}$ | | |
| Trace metals | | | | | $\frac{3/3}{3}$ | | | |
| **Topography** | | | | | | | | |
| Slope | | | | | | $\frac{3/3}{3}$ | | |
| Aspect | | | | | | $\frac{3/3}{3}$ | | |

Table 8.3. Measurability Matrix[1] For Significant (Rank of 3/3 Or Higher on Cause Effect Matrix) Modular Development Impacts[2] (Continued)

| | Source of Impact | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Underground retort construction | Cumulative construction activities | Dewatering and reinjection | Atmospheric venting | Storage of raw shale ore | Storage of topsoil | Habitat modification | Revegetation |
| Vegetation | | | | | | | | |
| Productivity | | 3/3<br>2 | | | | | 3/3<br>3 | 3/3<br>3 |
| Range condition | | 3/3<br>2 | | | | | 3/3<br>3 | 3/3<br>3 |
| Community composition | | 3/3<br>2 | | | | | 3/3<br>4 | 3/3<br>3 |
| Distribution | | 3/3<br>2 | | | | | | 3/3<br>3 |
| Cover, density | | 3/3<br>2 | | | | | 3/3<br>4 | 3/3<br>3 |
| Browse condition | | 3/3<br>1 | | | | | 3/3<br>3 | 3/3<br>3 |
| Small mammals | | | | | | | | |
| Relative abundance | | | | | | | 3/3<br>2 | 3/3<br>2 |
| Distribution | | | | | | | 3/3<br>3 | 3/3<br>3 |
| Species composition | | | | | | | 3/3<br>3 | 3/3<br>3 |
| Large mammals | | | | | | | | |
| Relative abundance | | 3/3<br>2 | | | | | 3/3<br>2 | 3/3<br>2 |
| Distribution | | 3/3<br>2 | | | | | 3/3<br>2 | 3/3<br>2 |
| Avifauna | | | | | | | | |
| Relative abundance | | 3/3<br>2 | | | | | 3/3<br>2 | 3/3<br>2 |
| Distribution | | | | | | | 3/3<br>3 | 3/3<br>3 |
| Species Composition | | | | | | | 3/3<br>3 | 3/3<br>3 |
| Periphyton | | | | | | | | |
| Relative abundance | | | 3/3<br>3 | | | | | |
| Species diversity | | | 3/3<br>3 | | | | | |
| Habitat | | | 3/3<br>3 | | | | | |
| Productivity | | | 3/3<br>3 | | | | | |
| Benthos | | | | | | | | |
| Relative abundance | | | 3/3<br>3 | | | | | |
| Species diversity | | | 3/3<br>3 | | | | | |
| Habitat | | | 3/3<br>3 | | | | | |

[1] Measurability values are defined as follows: 1=Not measurable, 2=Slightly measurable (with statistical confidence), 3=Moderately measurable, 4=Very measurable, 5=Extremely measurable.

[2] Upper values represent importance - magnitude from cause-effect matrix. Lower value represents measurability.

scored 3/3 or higher on the cause-effect matrix were ranked for measurability. Measurability is defined in terms of statistical confidence. Impacts or parameter values which can be measured with a high degree of statistical confidence were assigned higher ranks than those which cannot be measured with this high level of confidence.

Criteria for ranking measurability are listed below:

1-Not measurable with any degree of confidence
2-Measurable with a small degree of confidence
3-Measurable with a moderate degree of confidence
4-Measurable with a high degree of confidence
5-Measurable with an exceptional degree of confidence

Triplicates of $\frac{3/3}{3}$ or higher represented potentially important impacts which could be monitored with a reasonable degree of accuracy by measuring either the source of the impact and/or the resulting changes in the affected environmental components. These sources and/or environmental components were then included in the draft program. Additional steps were necessary, however, before the selection of monitoring parameters was finalized, as described below.

The second question of "how" remained to be answered. Several considerations were paramount to this discussion:

1. How do changes in the environmental components caused by development effect changes in other components?
2. How can these secondary changes be identified and tracked?
3. How can non-development related changes be separated from changes caused by development?
4. Can cause-effect be statistically verified?
5. Can long-term trends be identified and/or predicted?

6. Will it be possible to collect statistically reliable data without inducing sampling bias and environmental impact on the system in question?
7. Are non-statistical tests available which will adequately address the question?
8. Will the costs of collecting statistically reliable data be justified by the usefulness of the data acquired?

Both C-b and C-a approached this problem from a systematic viewpoint, developing an organizational framework from which to work, or as you will, a model. To quote C-b, "Institution of such an organizational framework automatically produces a model of the ecosystem. A model is merely an abstraction that tries to capture the essential portions of a system in less detail than would be required to reconstruct the entire system. For example, simple verbal descriptions of ecological interactions are models--in this case, word models. Topographic maps are models. Matrices and box-and-arrow diagrams, such as appear in Volume V, are also models. Mathematical equations and the computer programs to solve them are forms of more complex models" (C-b Shale Oil Venture, 1974-1976 Final Report, Vol. 5, p. 6).

Simple qualitative conceptual models of Tract C-b functions, in the form of matrices and box-and-arrow diagrams, are discussed in Volume 5 of the Final Report just referenced. The effect generators and effect receptors identified for C-b are nearly identical to equivalent components identified for Tract C-a in previous RBOSC reports (RBOSP, March 1976; RBOSP, May 1977a; RBOSP May 1977b; RBOSC, May 1977c).

In order to identify interrelationships among environmental components on Tract C-a and provide a means to track concurrent changes among interacting components, RBOSC developed a comprehensive interactions matrix (a conceptual model) for Tract C-a. In this model, major interactions between abiotic components, between biotic components, and between abiotic-biotic components were identified and ranked. Major ecological components included in the model were those identified from baseline studies and used in the "cause-effect" matrix analysis. Two ranking values were used--ecological importance and specific importance to the Tract C-a situation. They were ranked as follows:

| First Value<br>Ecological Importance | Second Value<br>Importance to Tract C-a System |
|---|---|
| 1 - none/not applicable | 1 - None/not applicable |
| 2 - Slightly important | 2 - Slightly important |
| 3 - Moderately important | 3 - Moderately important |
| 4 - Very important | 4 - Very important |
| 5 - Extremely important | 5 - Extremely important |

Judgements on the ecological importance (first value) were based on a knowledge of semi-arid ecosystems, the literature, and the application of well-known ecological principles. Judgements of the importance of an interaction to Tract C-a (second value) were based on qualitative and quantitative baseline data and on the interpretations of experts who studied the system in detail during baseline studies. Information presented in previous reports (RBOSP, March 1976; RBOSP, May 1977a; RBOSP, May 1976; RBOSP, May 1977c) was used extensively to identify and evaluate the potential interactions among physical and biological parameters. Evaluation of interactions was accomplished by rating the influence of one parameter on another prameter. Even with this simplification technique, a staggering number (over 5,000) of potential interactions was examined. In lieu of development of a computer simulation model, which would require the input of thousands of bits of data many of which are not available from baseline studies, RBOSC utilized experts in each discipline to group and describe the major interactions among Tract C-a components. These experts based their rankings on both qualitative and quantative analysis of the baseline data, as well as classical ecological literature and other related studies. Specific analyses techniques used in examination of baseline data (RBOSP 1976; RBOSP 1977a; RBOSP 1977b; RBOSP 1977c) are discussed in greater detail within each technical section. A few of the more important techniques which were used in analyzing baseline data are listed below:

Baseline Data Analysis Techniques

1) Correlations of gaseous air quality parameters (e.g., $SO_2$, HC, $NO_x$, $O_3$) with various meteorological variables (wind speed, wind direction, delta temperature).
2) Time series analyses of hydrocarbon and ozone concentrations versus time of day.
3) Correlation of $NO_x$ concentrations with $O_3$ concentrations.
4) Correlation of $O_3$ concentrations with solar insolation valves and relative humidity.
5) Cumulative frequency distribution for ozone and particulate concentrations.
6) Correlations between particulate concentrations and wind speed and relative humidity.
7) Correlations of particulate concentrations between sites.
8) Seasonal and annual summaries of air quality and meteorology data.
9) Statistical analysis of inversion occurrences of the region.
10) Seasonal and annual wind speed and direction joint frequency distributions.
11) Time series analysis of wind speed and air temperature by hour of day for each season.
12) Correlation of wind speeds between sites.
13) Correlation of wind speed and direction at four sites.
14) Time series analysis of wind direction by year (persistence).
15) Seasonal temperature profiles.

16) Time series analyses of surface water flow over a $2\frac{1}{2}$-year period by month.
17) Correlations between surface flow, conductivity, and suspended sediment flow.
18) Frequency distributions for occurrence of water quality constituents.
19) Predictive analysis of expected water quality by regression analysis.
20) Discrimanant analysis of relationships betweeen major anions and cations in surface waters of the tract.
21) Cluster analysis of water quality types for the area.
22) Correlation matrix analyses for surface water quality constituents.
23) Multivariate factor analyses on pooled water quality data.
24) Seasonal summaries of dominant aquatic biota by habitat type.
25) Generation of diversity indices for aquatic biota in the area by habitat type.
26) Length/frequency distribution of fish species collected from the study area.
27) Derivation of condition factors for selected fish species collected during baseline.
28) Analysis of variance between habitats on the basis of total numbers of benthos and periphyton.
29) Analyses of variance to determine differences in total numbers of periphytic or benthic organisms between years.
30) Statistical power study to assess benefits of collecting three versus two replicate samples for periphyton and benthos.
31) Correlation matrix analyses of relative changes in water depth in the alluvium over a $3\frac{1}{2}$ year period.
32) Time series analyses of residual water levels in the upper aquifer.
33) Frequency distributions of sodium concentration in groundwater.

34) Time series analyses of total dissolved solids in groundwater over a 2½ year period for several monitor locations.
35) Cluster analyses of groundwater quality.
36) Correlation matrix analyses of alluvial and upper and lower aquifer water quality.
37) Factor analyses of chemical constituents in alluvial, upper and lower aquifers.
38) Time trend analysis of sodium concentration in the upper aquifer over two years.
39) Time trend analyses of selected water quality factor values.
40) Discriminant function analysis of chemical differences of the three Tract C-a aquifer system.
41) Correlation of micronutrient levels in soils on and off tract.
42) Comparison of soil constituents as a function of depth.
43) Analysis of variance of production in the grass-forb stratum within the grazing exclosure on Tract C-a.
44) Calculation of browse conditions in two major habitat types for the area.
45) Comparison of forage production with snowfall accumulation.
46) Principal component analysis for 46 soil variables.
47) Hierarchial cluster analysis of soils data from 352 samples.
48) Correlation matrix analysis for soil variables.
49) Calculation of community coefficients and percentage similarity between vegetation types on tract.
50) Calculation of adequate sample size for each vegetation type.
51) Calculation of adequate sample size among vegetation types.
52) Spearman rank correlations between vegetation and soil properties.
53) Spearman rank correlations between vegetation and cumulative precipitation.
54) Spearman rank correlations among various soil traits.
55) Calculation of diversity indices for small mammal trapping grids.

56) Determination of macrohabitat affinities of small mammal species from the study area.
57) Time series analysis of chipmunk body weights versus time over 2 years.
58) Time series analysis of seed diets for chipmunks over 2 years.
59) Time series analysis of home range distances for two small mammal species by season over 2 years.
60) Species diversity calculations for small mammal species.
61) Seasonal time series analysis of mule deer pellet groups for the area.
62) Comparison of mule deer pellet plot numbers with vegetation type by season.
63) Calculation of avian species diversity for the tract.
64) Disperion modelling for air borne pollutant releases.

The conceptual model developed through this matrix approach served to answer the first two components of the "how" question - 1) how do changes in one component affect other components, 2) how can these secondary changes be identified and tracked. Design and implementation of the monitoring program in consideration of this model and the interrelationships identified therein will hopefully provide answers to the other components of this question.

The control/treatment concept for sampling will serve to identify and separate development impacts from naturally occuring changes. Predictive statistical tests will be applied to appropriate data sets whenever feasible to attempt to identify future long-term impacts. The multiple use of sampling sites for collection of data on more than one parameter will allow direct comparisons of driving and state variables. Sampling bias will be avoided to the greatest degree possible and program elements altered, as necessary to avoid sampling perturbations. Nonstatistical tests will be employed on low intensity data and to supplement quantitative data where necessary. Application of these procedures and careful placement of sampling sites will serve to hold monitoring costs within reasonable bounds.

Since this is designed as a dynamic monitoring program, it is expected that data analyses techniques will be altered as conditions warrant to provide the flexibility necessary to keep the program sensitive to natural and man-induced environmental perturbations, changes in design plans, and new knowledge of the intricies of the system. Therefore the proposed analyses described below are tentative in nature, at best. These analyses are designed to provide information relative to the interrelationships defined in the matrix model. Basic analyses to be employed for specific data sets are discussed within individual technical sections.

The analyses described in this section will address and satisfy Section 1(c)(2)(d) of the prototype oil shale lease which requires the lessee to "...study, and report to the Mining Supervisor on ecological interrelationships ..."

## 8.1 ABIOTIC-ABIOTIC RELATIONSHIPS

As pointed out by Tract C-b: "Interrelationships among abiotic components and processes in the Tract C-b environmental system are important primarily because the abiotic portion of the system usually functions as a medium for transporting environmental perturbations between the source and the biota of the system. The most important media, of course, are air and water" (C-b Shale Oil Venture 1974-1976 Final Report, Volume 5, p. 133). Naturally occuring relationships between abiotic components are not of direct concern in the assessment of the effects of oil shale development. However, it is important to separate natural events from man-induced changes to identify the nature and extent of development-related impacts that may arise. A large number of abiotic-abiotic relationships were identified for Tract C-a (RBOSC 1977a). A few of these relationships are identified below.

- Influence of precipitation on surface water (quality, quantity, and velocity).
- Influence of atmospheric contamination on the quality of precipitation.
- Influence of deep aquifer quality on alluvial aquifers
- Influence of groundwater quantity on surface water quantity.
- Influence of groundwater quality on surface water quality.
- Influence of groundwater flow/movement on surface water quantity and quality.
- Influence of groundwater level on surface water quantity and quality.
- Influence of groundwater availability/consumption on surface water availability.
- Influence of surface water flow on surface water sediment load.
- Influence of surface water flow on stream bed erosion.
- Influence of soil erosion on surface water sediment load.
- Influence of atmospheric contamination on soil chemistry.
- Influence of slope on drainage basin characteristics.
- Influence of slope on soil erosion potential.
- Influence of drainage basin on surface water flow and velocity.
- Influence of terrain stability on surface water sediment load.

Climatic factors typical of Tract C-a (e.g. rainfall events, snowfall, wind patterns, solar insolation) are not likely to be altered by development of Tract C-a. Therefore, changes in related abiotic components (surface water flows, groundwater recharge and availability, etc.) which result from natural climatic variations cannot be attributed to development. The value of studying such relationships lies in being able to recognize natural variations and to distinguish these from man-induced effects.

Abiotic components which are subject to development perturbations include: ambient air quality, ground and surface water quantity and quality, soil erosion potential, slope characteristics, and soil chemistry. Changes in ambient air quality can be expected as a result of emissions from stacks, vehicle and generator exhausts, and vehicular movement. Introduction of contaminants into the atmosphere can potentially affect the quality of precipitation falling in the region. However, this impact is difficult to monitor because of current limitations in state-of-the-art sampling techniques in lightly industrialized areas. Contamination of samples has been shown to contribute more to the concentrations of constituents in the samples than the air contamination source in such cases. In view of the limited industrial activity in the Tract C-a area in combination with the difficulty of acquiring accurate data on precipitation chemistry, RBOSC has chosen not to attempt characterization of precipitation quality on Tract C-a. Data from other studies (including stack sampling) will be used to determine if atmospheric contamination is significant. However, as industrial activity in the area increases, or in case of upset conditions, RBOSC may need to initiate precipitation quality sampling. Information from a variety of sources, e.g. ambient air quality monitors, water quality analyses, soils chemistry data and vegetation condition data will be compared with contaminant release data to assess the need for additional sampling and analysis.

Effects on groundwater quality and quantity are anticipated as a result of development. Several components of the monitoring program are designed to measure these effects including water quality of alluvial and deep oil shale aquifers, water levels, in various aquifers, and drawdown data (see Section 6.0 of this scope). In addition, modelling results will be used to further characterize these effects. Corresponding changes in surface water flows and quality as groundwater effects are noted will be traced through collection and analysis of flow and quality data. A variety of data analysis techniques will be used to identify these relationships including:

- Discriminant function analysis of chemical differences among the three aquifer systems.
- Factor analysis of the chemical consitutents in the three . aquifer systems.
- Time trend analysis of changes in water quality or quantity over time.
- Correlation analyses of ground and surface water quality.
- Correlation of surface flow with groundwater usage.

The third most important abiotic environmental component is likely to be affected by development activities is the soil stratum. Potential effects include contamination of soils from atmospheric release, increased erosion, changes in slope aspect and stability, and changes in water holding capacity (and runoff). The occurrence of such effects will be tracked by collection and analysis of soils samples (when triggered by contaminant release data), aerial photography, turbidity measurements, sediment and runoff data. Analysis of corresponding changes in related ecosystem components as the soil stratum is affected will be accomplished by the following techniques:

- Spearman rank correlations of trace metal concentrations in releases and in soils samples.
- Trend analyses of soil chemistry over time.
- Graphical comparisons of precipitation, runoff flows, and denuded acreage.
- Trend analysis of runoff and surface flows over time (baseline through MDP monitoring).
- Comparisons of sediment loads in relation to disturbed acreage.
- Comparison of TSP concentrations in relations to distance from source.
- Time trend analysis of TSP concentrations over time.

As the data are evaluated and the interrelationships are more fully understood, data analyses techniques will be re-examined and adjusted as necessary to maximize the utility of the data.

## 8.2 ABIOTIC-BIOTIC RELATIONSHIPS

Nine abiotic-biotic relationships in the Tract C-a area were ranked as high-level by the experts who studied the data:

- Influence of precipitation quantity on vegetation production.
- Influence of precipitiation quantity on vegetation cover and density.
- Influence of precipitation quantity on mule deer migrations.
- Influence of ambient air temperature on large mammal migrations.
- Influence of soil chemical characteristics on plant community distribution.
- Influence of soil trace metals on trace metals in plants.
- Influence of soil chemical characteristics on plant community composition.
- Influence of soil physical characteristics (e.g. depth) on plant cover.
- Influence of slope/aspect on vegetation cover or composition.

Aspects of the climatic regime of critical importance to plants and wildlife in the Tract C-a study area are distribution and amount of rainfall and snowfall, length of the growing season, maximum and minimum temperatures, and the frequency and velocity of wind (RBOSP Progress Report 10 1977, Terrestrial Section, p. 15). However, RBOSC's activities on Tract C-a are not expected to appreciably affect any of these climatic factors. It is important, though, to be able to track the influences of natural variations in these factors on biotic components of the tract to distinguish natural variation from man-induced variation. Tracking of such interactions will be attempted by correlative analyses, time trend comparisons and graphical display techniques.

Changes in vegetation identified by study of aerial photographs may trigger additional phytosociological sampling to pinpoint the extent and type of change which has occurred. The cause(s) of the change will be investigated by comparision of baseline and monitoring data; review of development activities (e.g. dewatering, releases of air borne pollutants); consideration of wind patterns, climatic factors and regional effects; and comparison of control-treatment areas. Specific data analyses procedures will be designed after more information is available on the nature of the change and in accordance with the resolution of the data available.

Effects of precipitation events on mule deer occurrence and use of the area may be difficult to assess because of the sporadic nature of snowstorms and the variation in accumulations of snow in the study area. These parameters will be compared to the greatest extent possible by plotting mule deer pellet plot data on topographic maps and utilizing snow depth data for the tract. The relationship between mule deer use and vegetation type occurrence will be studied by plotting deer-use isopleths on vegetation distribution maps or photographs. Over time, changes in deer use should be discernible.

The failure of mule deer to utilize a given area will be studied by the following comparative statistics:

- Spearman rank correlations of mule deer densities versus cumulative snow depth over a period of 6 years or more.

- Time series analysis of mule deer densities versus time over a period of years or several seasons.

In the event of discernable major changes in vegetative type distribution, a number of additional studies may be triggered. Among these are:

- Soil moisture studies
- Soil chemistry studies
- Analysis of trace metal content in plants from affected and control areas
- Additional small mammal and avifauna studies
- Additional range and browse utilization studies
- Additional deer density studies

Analysis and review of these and other data will aid in identification of the cause of noted changes. However as expressed by C-b, "Most of the abiotic effects impinging upon the biota of the environment....will be felt through interactions among the biota themselves. For example, disturbed vegetation associated with man's activities in the area will affect the general habitat of plants and animals. It is difficult to say at this time how widespread the effect would be or to what degree specific plants or animals would be affected." Therefore, an analysis of biotic-biotic relationships is an essential step in attempts to identify "causes" of these changes, as discussed in the following section.

## 8.3 BIOTIC-BIOTIC RELATIONSHIPS

The biotic interrelationships on Tract C-a fall into two distinct ecosystem response units - the aquatic system and the terrestrial system. Interactions between the two systems are limited and difficult to identify or to test. Therefore the interrelationships to be addressed during the MDP studies will be limited to interactions between terrestrial biota and to those between aquatic biota.

Important interrelationships between terrestrial biota on Tract C-a identified as a result of analysis of baseline data include:

- Predator-prey relationships
- Food availability and animal abundance, behavior, and distribution
- Cover (habitat) condition in relation to animal survival and population increase

Data collected during the MDP program will be evaluated to quantify these relationships, where possible, and to identify the significant components of each interrelationship for the Tract C-a ecosystem. If components can be adequately identified, it will be possible to adjust the monitoring program to provide more meaningful data. Caution must be exercised however, so that premature conclusions regarding "cause" for apparent changes in the relationship are not drawn.

Food is the single most important ecosystem component regulating the survival and success of animal populations. In the case of carnivores, the availability of prey determines the presence of absence of the predator. For foraging animals, the condition or productivity of the vegetation is most important.

Unfortunately, predator-prey relationships are particularly difficult to quantify because of the difficulties in determining population status of either the predator or the prey. Coyote studies conducted during baseline failed to provide accurate information on populations of this predator in the area. This was also true for other major predators. As a result, quantitative predator-prey studies are not planned for the MDP period. Qualitative data will, however, be available, including field notes relating to rabbit and coyote sightings in the area, raptor sightings, road kill counts and other similar data. These qualitative data will be used by the Tract C-a field biologist during assessments of development impacts and while preparing reports on the status of the tract environment to complement other, more quantitative data.

Availability of forage will be determined by a number of techniques including aerial photography, range condition and utilization, browse condition and utilization, photo plots, and phytosociological studies.

Data from these studies will be compared with user data (e.g. mule deer density, cattle allotments, small animal data) to characterize the terrestrial response units of the ecosystem.

Analyses will include:

- Spearman rank correlations of mule deer densities versus browse use from control and treatment plots.
- Spearman rank correlations between estimated numbers of cattle, feral horses, and mule deer by each year and estimate of range utilization.
- Time trend analysis of mule deer densities versus browse utilization over time.

Although it would be interesting to conduct similar analyses for other animals (e.g. small mammals and birds) we do not anticipate fine enough resolution of these data to justify such comparisons. The data will be evaluated, however, to ascertain suitability for additional analyses. If they are suitable, similar analyses will be completed.

Since vegetation production is closely related to cover, many of the analyses just described will provide insight into the relationship of habitat condition and animal survival and success. These analyses coupled with surveillence of discrete habitat changes and animal behavior will help answer questions related to these interrelationships.

The analysis of aquatic ecosystem responses will be directed toward the two most significant components of that ecosystem - the periphyton and benthos communities. Baseline studies have indicated that these two groups significantly impact one another. Periphyton serves as a major source of food for the benthic community and therefore limits and is limited by the benthic component. A series of analyses will be carried out to further define the interrelationship of these two groups:

- o Comparison of relative numbers of periphyton and benthos at similar locations over time
- o Correlations of species diversities of each group with baseline values
- o Time series graphs illustrating the fluctuations in species diversity, and relative abundance, over time as development proceeds.

## 8.4 SUMMARY

As more data are collected and analyzed, additional insight regarding the function of various components of the ecosystem will be gained. With time, the sampling program and the analyses will be modified to maximize the usefulness of this newly acquired knowledge. It is unwise to anticipate that we will answer all the questions that will be asked about the terrestrial and aquatic ecosystems in the Tract C-a area during the life of this project. We should be able, however, to add a great deal of information to the existing data base which will aid researchers, regulatory agencies, and industry in the environmentally sound development of the oil shale region. In application of these data for the environmental assessment of the oil shale development impacts we encourage readers to reveiw Auberbach (1978) and Cooper (1978). We should not overestimate the role of stress in ecosystems, nor should we overrate our abilities to measure it.

## LITERATURE CITED


Auberbach, S. I. 1978. Current Perceptions and Applicability of Ecosystem Analysis to Impact Assessment. Ohio J. Sci. 78(4):163-174.

Cooper, W. E. 1978. Systems Predictions: The Integration of Descriptive Experimental and Theoretical Approaches. Ohio J. Sci. 78(4):186-189.

RBOSP. 1976, Detailed Development Plan Tract C-a. Baseline Conditions. Gulf/Standard. Denver, CO. Vol. 2. March 1976.

RBOSP. 1977a. Final Environmental Baseline Report. Gulf/Standard. Denver, CO. Two volumes. May 1977.

RBOSP. 1977b. Quarterly Progress Report 10. Gulf/Standard. Denver, CO. May 1977.

RBOSP. 1977c. Revised Detailed Development Plan, Tract C-a. Environmental Protection and Monitoring. Gulf/Standard. Denver, CO. Vol. 3 May 1977.

C-b Shale Oil Venture. 1974-1976. Environmental Baseline Program Final Report. System Interrelationships. Ashland Oil, Inc./Occidental Oil Shale, Inc. Grand Junction, CO. Vol. 5 Nov. 1974-Dec. 1976.

C-b Shale Oil Venture. 1978. Development Monitoring Program for Oil Shale Tract C-b. Supplemental Information. Ashland Oil, Inc./Occidental Oil Shale, Inc. Grand Junction, CO. July 1978. 170 pp + appendices.

## 9.0 REPORTING AND DATA MANAGEMENT

Mid-year data reports are submitted on August 31 (or nearest work day following the 31st) of each program year (Table 9.1). Mid-year reports contain reduced and raw data collected during the specified reporting period and short narrative descriptions of results. Where appropriate, (e.g., Air Studies program) data are placed on magnetic data tapes. One copy of each edited tape is submitted for data collected during the previous six months when the mid-year report is submitted.

The year-end report is submitted on March 31st (or nearest work day following the 31st) for each program year. Year-end reports contain raw and reduced data for the previous reporting period (see Table 9.1), yearly summaries, analyses and interpretations of the 12-month data set, and, where appropriate, comparisons between years, seasons, and other data sets (e.g., DOW data). The year-end report is designed to continually update the data base for the tract. Trends are rated, anomalies are flagged, and long term evaluations are made. Developmental perturbations are identified, and assessed as they occur. Once identified, possible mitigation procedures are recommended. Magnetic tape data for the reporting period will be submitted with the report. RBOSC is currently developing an in-house data management system which will be used for data storage and retrieval. When fully operational, the system will provide for easy access and retrieval of data, and will facilitate statistical analyses and data comparisons. All data entry and reduction will be performed according to documented quality assurance procedures to insure the credibility of the data base.

Table 9.1. RBOSC MDP Environmental Monitoring Program Report Schedule

| Report | Data Collection Period[1] | Report Submittal Date |
|---|---|---|
| Monitoring Report 1 | Sept. - Nov. 1977 | Feb. 28, 1978 |
| Monitoring Report 2 | Dec. 1977 - May 1978 | Aug. 31, 1978 |
| Monitoring Report 3 | June - Nov. 1978 | Mar. 31, 1979 |
| Monitoring Report 4 | Dec. 1978 - May 1979 | Aug. 31, 1979 |
| Monitoring Report 5 | June - Nov. 1979 | Mar. 31, 1980 |
| Monitoring Report 6 | Dec. 1979 - May 1980 | Aug. 31, 1980 |
| Monitoring Report 7 | June - Nov. 1980 | Mar. 31, 1981 |
| Monitoring Report 8 | Dec. 1980 - May 1981 | Aug. 31, 1981 |
| Monitoring Report 9 | June - Dec. 1981 | Mar. 31, 1982 |

1/ Data not received during the reporting period will be reported in the report for the period following receipt.